KIPP & ZONEN
SINCE 1830

Brewer MkIII

Spectrophotometer

Operators manual

REVISION HISTORY				
REV	DESCRIPTION	DCN #	DATE	APPD
--	Initial Release	891	99-08-17	
A	Update	55	05-10-21	KBo
B	Update		06-06-26	KBo
C	Update		07-10-16	KBo
D	Update		08-10-16	KBo
E	Update		08-11-14	KBo

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KIPP & ZONEN 's obligation under this warranty is strictly and exclusively limited to repairing or replacing, at KIPP & ZONEN 's discretion, any such equipment and / or parts thereof which have failed under normal use and service. Expressly this warranty does not apply to any equipment and / or parts which have been improperly installed, been subject to abuse, neglect and / or accident.

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Should an extended warranty be purchased, then the aforementioned in its entirety is applicable for the entire period of time covered by said extended warranty.

Recommendations by Environment Canada

Mark III Brewer Ozone Spectrophotometers are recommended by Environment Canada (EC) as the significantly superior model of Brewer instrument with which to measure ozone in the ultraviolet (UV) region of the spectrum. EC strongly discourages the use of other models of the Brewer instrument for the measurement of ultraviolet radiation or ozone in the UV because of the much poorer stray light performance of the single monochromator versions of the instrument.

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1 SYSTEM OVERVIEW

Refer to Figure 1.1

Brewer Spectrophotometers are a family of scientific instruments, which measure Ultra Violet radiation in the solar spectrum. By examining the differential absorption of select wavelengths in the UVB portion of the spectrum, determinations of Total Column Ozone and Total Column Sulpher Dioxide are inferred. In addition, especially with the MKIII double monochromator instrument, accurate spectral intensity profiles of UV radiation in the 286.5 nm to 363 nm range are measured.

It is well recognized by the scientific community that marked fluctuations in atmospheric ozone and sulphur dioxide concentrations are linked to a variety of adverse environmental conditions. The ozone layer, which shields the Earth from the harmful effects of solar ultraviolet radiation, is believed to be vulnerable to attack by fluorocarbons and other effluents. Many scientists fear its depletion may irreversibly alter world climatic patterns.
Atmospheric sulphur dioxide is closely associated with the 'acid rain' phenomenon which, like ozone depletion, has implications for the global environment.

Today's concern over the vulnerability of the ozone layer to destruction by atmospheric pollutants has increased the demand for high-quality, globally-distributed, total Ozone and UV Spectral measurements from a ground-based network of instrumentation. Since the early 1980's, the Environment Canada (EC) has conducted the development of the Brewer Spectrophotometer for the purpose of supplementing instrumentation in the World Ozone Network. Though the Dobson instrument has served its purpose well since the 1930s, the Brewer Ozone Spectrophotometer is today becoming the instrument of choice for researchers studying Ozone, Sulphur Dioxide, and UV radiation.

At the request of the World Meteorological Organization, the EC has endeavored to make the Brewer Spectrophotometer commercially available to the international scientific community. The instrument and its accompanying accessories are manufactured and marketed under license by KIPP & ZONEN, Delft, The Netherlands. As of 1998, more than 80 Brewer instruments have been incorporated into the World Ozone Network and measurements are currently being taken at research establishments in more than thirty different countries.

The Brewer Spectrophotometer is the core component of a complete Brewer System which is comprised of the following:

Brewer Spectrophotometer
Solar Tracking System
IBM PC or compatible Computer operating Brewer Software

All of the above equipment is available from KIPP & ZONEN. The Brewer Spectrophotometer is supplied with a complete set of programs, which control all aspects of data collection and some analysis. The Computer is programmed to interact with an operator to control the Brewer in either a manual or fully-automated mode of operation.

In both the manual and semi-automated modes the operator initiates a specific observation or instrument test by typing a simple 'command' on the Computer keyboard. Raw data is automatically recorded on the Computer data drive, and real-time Ozone and UV results can be printed.
In the fully-automated mode, a ‘Schedule’ in the Computer controls all operations. The Brewer is automatically set to the proper observation configuration, then follows a user-defined observation schedule.
Data is stored and analyzed in the same manner as in the manual or semi-automated mode.

The Brewer is designed to recover from a power failure, and will resume scheduled operation subject to the computer system recovery, if the Brewer batch file has an automatic launch.

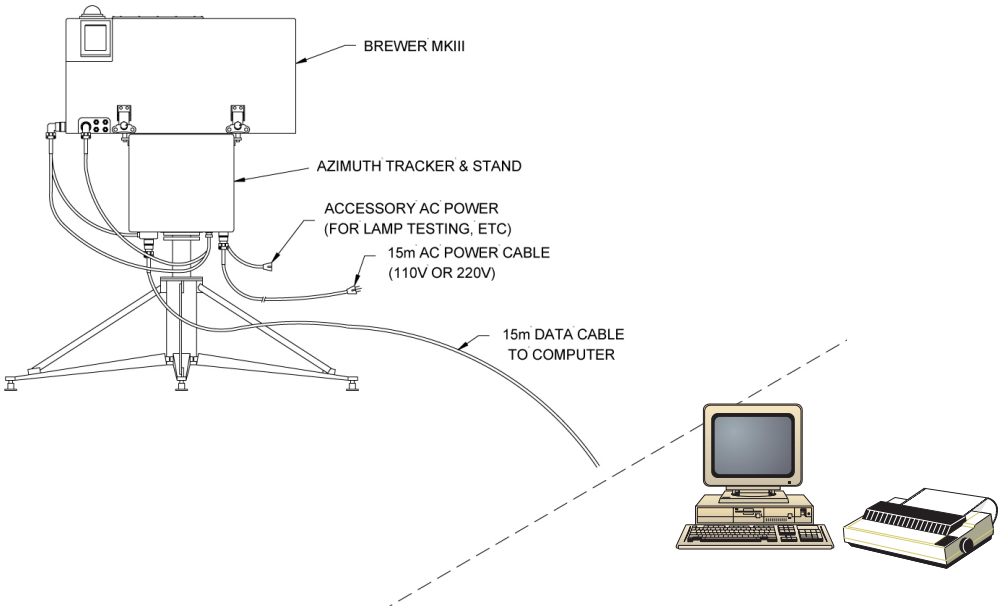


Figure 1.1: A Brewer System

2 SYSTEM DESCRIPTION

The Brewer MKIII Spectrophotometer is an optical instrument designed to measure ground-level intensities of the attenuated solar ultraviolet (UV) radiation. The Brewer contains two modified Ebert f/6 spectrometers, each utilizing 3600 line / mm holographic diffraction gratings operated in the first order.
The Brewer is designed for continuous outdoor operation and is therefore housed in a durable weatherproof shell which protects the finely-tuned internal components. The instrument operates reliably and accurately over a wide range of ambient temperature and humidity conditions.
Following is a brief description of the the major mechanical, optical, and electronic assemblies which make up the basic instrument. A more complete description of the electronic assemblies is provided in the Brewer Maintenance Manual.
The Brewer system is comprised of a Spectrophotometer, a Solar Tracker, and Computer equipment running Brewer control and data logging software.

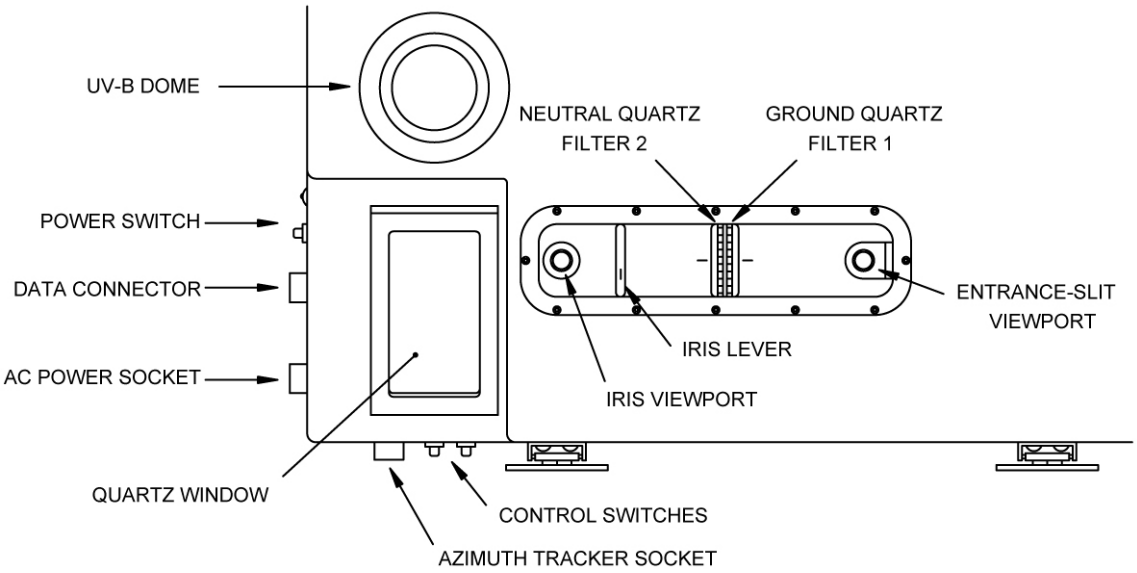


Figure 2.1: Top View of Brewer Cover

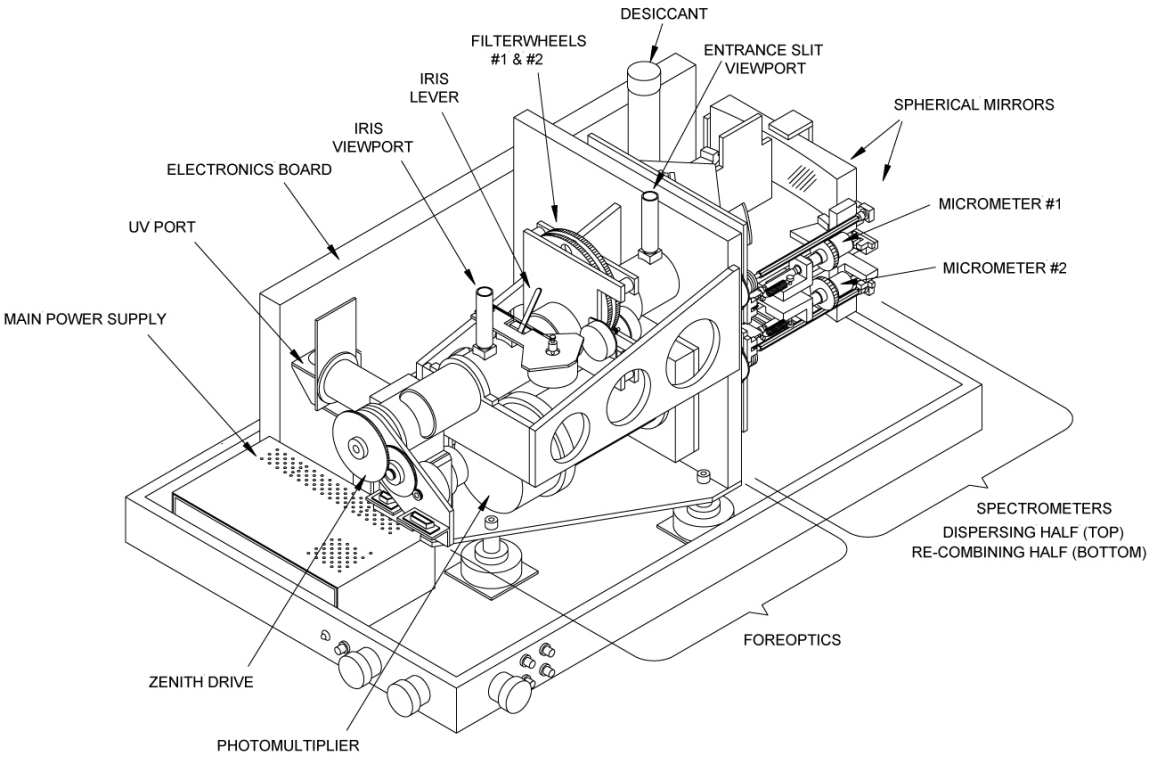


Figure 2.2: View of Brewer with Covers Removed

2.1 SPECTROPHOTOMETER

Table 2.1: Spectrophotometer Specifications

UV wavelengths:	'ozone' wavelengths (nm): 303.2 (Hg slit) , 306.3, 310.1, 313.5, 316.8, 320.1
Mercury-calibration	302.15 nm
Resolution	0.6 nm in UV
Stability	±0.01 nm (over full temperature range)
Precision	0.006 ±0.002 nm
Measurement range	286.5 nm to 363.0 nm
Exit-slit mask cycling	0.12 sec/slit, 1.6 sec for full cycle
O_3 Measurement accuracy	±1% (for direct-sun total ozone)
Ambient Operating temperature range (for more information see appendix F, Thermal Test)	0°C to +40°C (no heater) -20C to +40°C (with heater option) -50°C to +40°C (with complete cold weather kit)
Physical dimensions (external weatherproof container)	Size: 70 by 46 by 34 cm Weight: 34 kg (75 lbs)
Power requirements Brewer and Tracker	90 to 264 VAC 47 to 440 Hz

2.1.1 Mechanical Construction

Refer to Figure 2.1 and Figure 2.2.

The Brewer Spectrophotometer is housed in a weatherproof container constructed from two pieces - a base, to which all optical and electronic assemblies are anchored, and a removable cover. When the cover is fastened in place, a weatherproof seal is formed between the top edge of the base and the bottom of the cover. The dimensions of the assembled container are 70 x 46 x 34 cm. The Brewer instrument control panel can be viewed through a perspex window in the top of the cover. Viewing ports for both the iris and the spectrometer entrance slit are visible through this window.
In one corner of the cover is a 14cm deep, 35° inclined surface. A 6.35 cm by 14 cm hole has been cut from this surface to provide an opening which is properly positioned to pass direct sunlight or zenith skylight to the spectrophotometer. This opening is covered by a quartz window [QW 1], which is secured by a weatherproof seal. (Items enclosed by square brackets, [ ], are references to the Selected Parts List, Table 2-2, and Figure 2-5).
Three circular weatherproof connectors are mounted on the side of the Brewer base below the weatherproof seal. A six-pin male connector marked AC POWER connects to the 120V (or 240 V) AC power supply. A ten-pin female connector marked COMPUTER carries the RS-422 data communication signals. A ten pin male connector marked AZIMUTH carries motor control and monitor signals for the azimuth tracker.
All exposed surfaces of the spectrophotometer container and mechanical linkages are painted with an enamel for durability and to minimize radiative heating. All machined aluminum parts in the spectrophotometer system are black-anodized to minimize scattered light and provide a protective finish.
Mounted inside the Spectrophotometer is a cannister of desiccant which is designed to remove moisture from the air as the Brewer ‘breathes’ with changes in temperature from night to day. The desiccant is a ‘self indicating’ type, and can be conveniently removed, without tools, through the base of the instrument.
This cannister will NOT remove moisture from within the spectrophotometer, and bags or trays of loose desiccant are usually used for this purpose.

Moisture Sensor
As standard feature, the spectrometer is fitted with a Moisture Sensor. The sensor outputs the moisture content of the spectrophotometer housing in gm/m^3 and RH%, and can be used as an indication of moisture leakage problems, or when internal desiccant requires changing. Two humidity indicators are printed at the top of the Brewer screen: the absolute humidity in grams/m^3 and a temperature weighted moisture index. The moisture index is a relative number that indicates whether the desicant requires changing. Consistent moisture index values of greater then 10 means that the desicant should be changed.

Heater / Fan Assembly
A heater / circulating fan assembly is included as for in cases where it is desired to maintain constant temperature or good air mixing within the instrument. The air mixing feature is especially useful in moist climates, and it enables the internal desiccant to be exposed to the total air volume. In addition, the mixed air will give a more representitive value of moisture content if the Brewer is fitted with the moisture sensor option.

The heater will attempt to hold the Brewer’s internal temperature at or above a set minimum temperature. The minimun temperature can be set at 10°C or 20°C. The minimum temperature is selected by moving the jumper (J1) on the porportional heater controller (bolted to the Brewer foreoptics supports near the zenith prism):

Jumper setting	Minimum temperature
1-2	20°C
2-3	10°C

The default setting is a minimum temperature of 20°C.

Zenith Pointing System

Refer to Figure 2.3 and Table 2.3

A right-angle zenith prism [ZP 1] directs incoming light from the sun, the sky, or the test lamps onto the optical axis of the instrument. For zenith angles in the range 0° to 90° the sun, or sky, is viewed through an inclined quartz window. At zenith angle 180° the spectrometer views the calibration lamps, and at - 90° the teflon UV diffuser occupies the field-of-view.

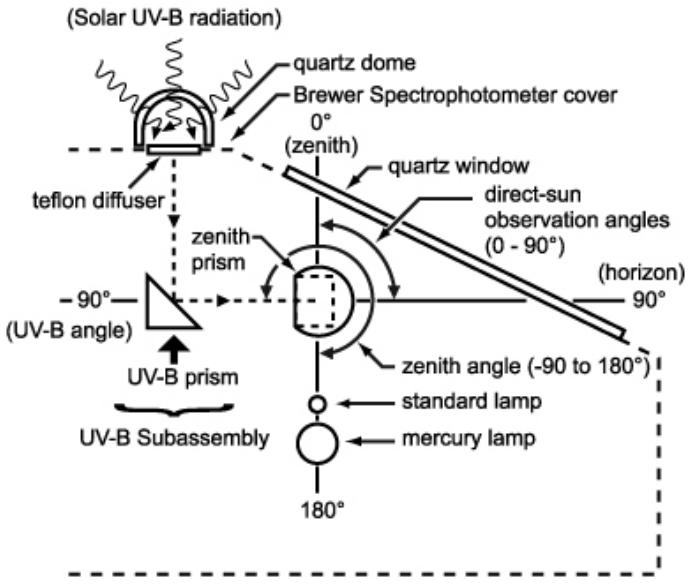


Figure 2.3: Zenith Prism Targets

Table 2.3: Spectrometer Targets for Various Zenith Angles

Zenith angle (°)	Object viewed by Spectrometer
0 to 90°	Sky or sun
180°	Calibration lamps
-90°	UV diffuser

The prism is mounted in a retainer which rotates in a dual-bearing system. The prism is rotated by a microprocessor controlled zenith stepper motor thru a 270-degree rotation range limited by end stops. This system provides the necessary hardware and electronics to enable the Spectrophotometer to track the sun or moon automatically in the Zenith angle. Automated Zenith positioning is performed by driving the Zenith Prism with a stepper motor mounted on the front end of the foreoptics frame. The zenith-stepper motor is controlled by the Main Electronics board.

Specifications of the Zenith Motor:

Resolution:	±0.13°
Accuracy (24 hours):	± 0.25°
Angular range:	0 - 270°

Table 2.2 Optical Components of Brewer Spectrophotometer

Identification	Description
AP 1	Fixed aperture, 11.18 mm
ES 1	Entrance slit plate, dia: 26.37 mm, thk: 0.10 mm Slit, length: 3.30 mm, width: 0.34 mm.
EX 1	Exit slit plate, length: 28.95 mm, width: 19.05 mm, thk: 0.10 mm Slits, length: 5.08 mm, width(3): 0.589 mm, width(3): 0.632 mm.
EX 2	Exit slit plate, dia: 26.37 mm, thk: 0.10 mm Slit, length: 5.08 mm, width: 0.632 mm.
FW 1	Filterwheel #1 made from aluminum gear material, with two ground G1-quartz disk, dia: 25.4 mm, width: 1.59 mm, and film polarizer, dia: 25.4 mm, width: 1.59 mm.
FW 2	Filterwheel #2, made from aluminum gear material with 5 neutral-density filters; each with dia: 25.4 mm, width: 1.59 mm; attenuations: 0.5, 1.0, 2.0, 2.5 decades (prepared from G1 quartz blanks)
GR 1,2	Grating, 3600 line/mm holographic plane reflectance, dia: 50 mm, thickness: 10 mm (Jobin-Yvon)
HL 1	Tungsten-halogen lamp, 12 V, 20 W, Osram 64425, mounting: Amel Socket for #28-8341 light source
IR 1	Iris diaphragm, aperture range: 2 to 12 mm (Edmund Scientific catalogue #40997)
LE 1	Lens, double-convex, G1-quartz, focal length: 25.4 mm, dia: 25.4 mm
LE 2	Lens, plano-convex, G1-quartz, focal length: 76.2 mm, dia: 25.4 mm
LE 3	Lens, plano-convex, G1-quartz focal length: 50.8 mm, dia: 25.4 mm
LE 4	Lens, plano-convex, G1-quartz, focal length: 76.2 mm, dia: 25.4 mm
LE 5,6	Correction lens G1 quartz, dia: 25.4 mm, radius 1: 170.0 mm, convex cylindrical, radius 2: 230.0 mm, concave spherical, coating: magnesium fluoride
LE 7 **MI 1,2** **ML 1**	Fabry lens, double-convex, G1 quartz, dia: 38.1 mm focal length: 38.1 mm Micrometer, metric, Starrett #463 MP,13-mm head, EDP #52444 Mercury lamp GTL3, Germicidal, 12 V, 4W Mounting: E17 - Edison Intermediate Screw, 17mm
PM 1	Photomultiplier, 30 mm, R7207-01
QW 1	Quartz window, G1 quality 7.62 by 15.24 by 0.48 cm
SL 1 **SM**	Slit mask, cylindrical sector, dia: 25.4 mm, thickness: 0.038mm Spherical mirror, radius: 324 mm, ground from pyrex blank of dimensions 25.4 by 165.1 by 50.8 mm, aluminized reflecting surface, coated with magnesium fluoride
VL 1 **VP 1,2**	Viewing lens, plano-convex, glass. dia: 15 mm, focal length: 112 mm Viewing prism, right-angle, glass 7 by 8 by 7 mm
ZP 1	Zenith prism, right-angle, G1-quartz, 31.75- by 31.75-mm square face

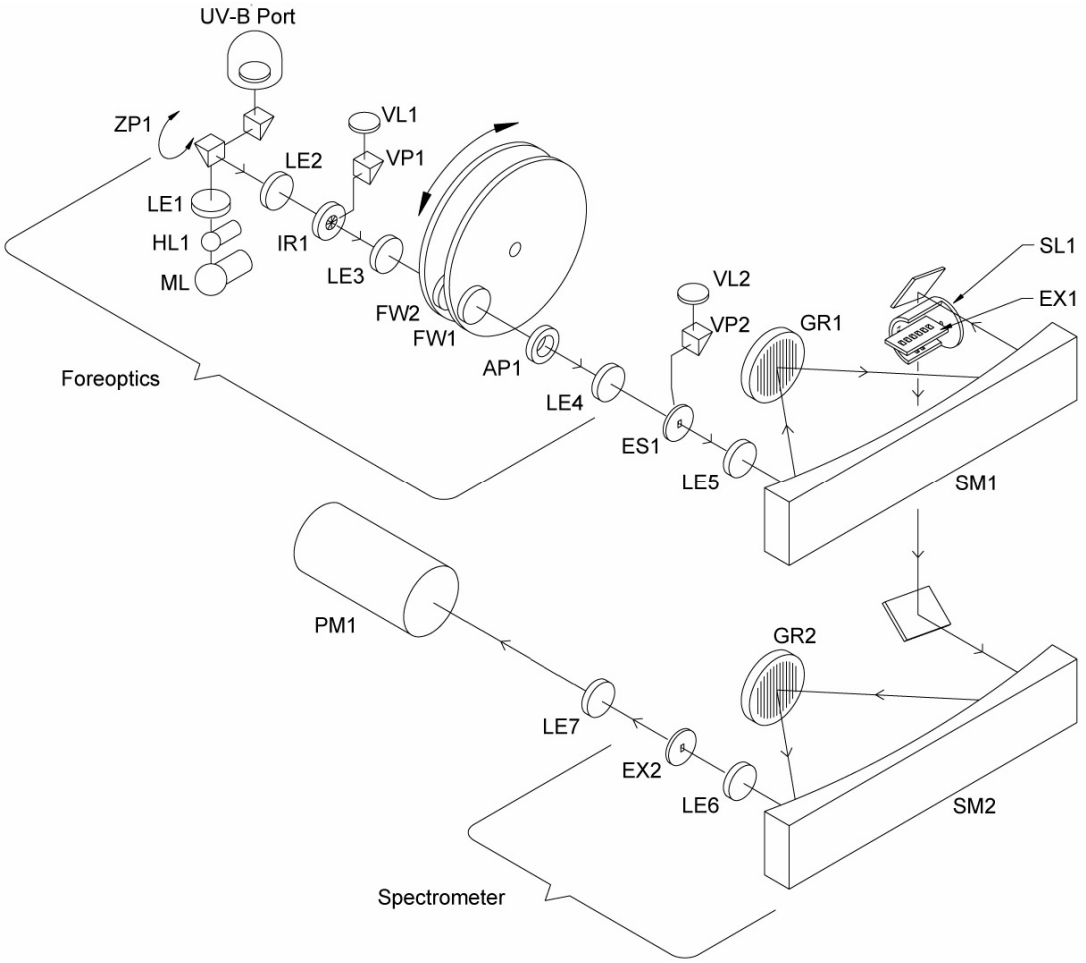


Figure 2.4: Optical Elements of Brewer Spectrophotometer

Lamp Assembly

A quartz-halogen lamp [HL 1] provides a well-regulated light source which is used as a reference for sensitivity measurements. The lamp is powered by a constant current source of nominal value 1.5 A, held to within 0.5% over a temperature range of -20° to +40° C. The intensity of the radiation from the lamp under these conditions is stable to within 5%. The filament of the lamp is placed at the focal point of a double-convex lens [LE 1] so that the light from the lamp is directed along the optical axis by the zenith prism.

Beneath the halogen lamp is a mercury discharge lamp [ML 1], which provides a line source for wavelength calibration. Ultraviolet radiation from the mercury lamp passes through the halogen lamp to the zenith prism. While the actual light intensity of the lamp is not critical (a variation of 50% over the operational temperature range is normal), it must remain stable to within 5% for short time periods (10 minutes).

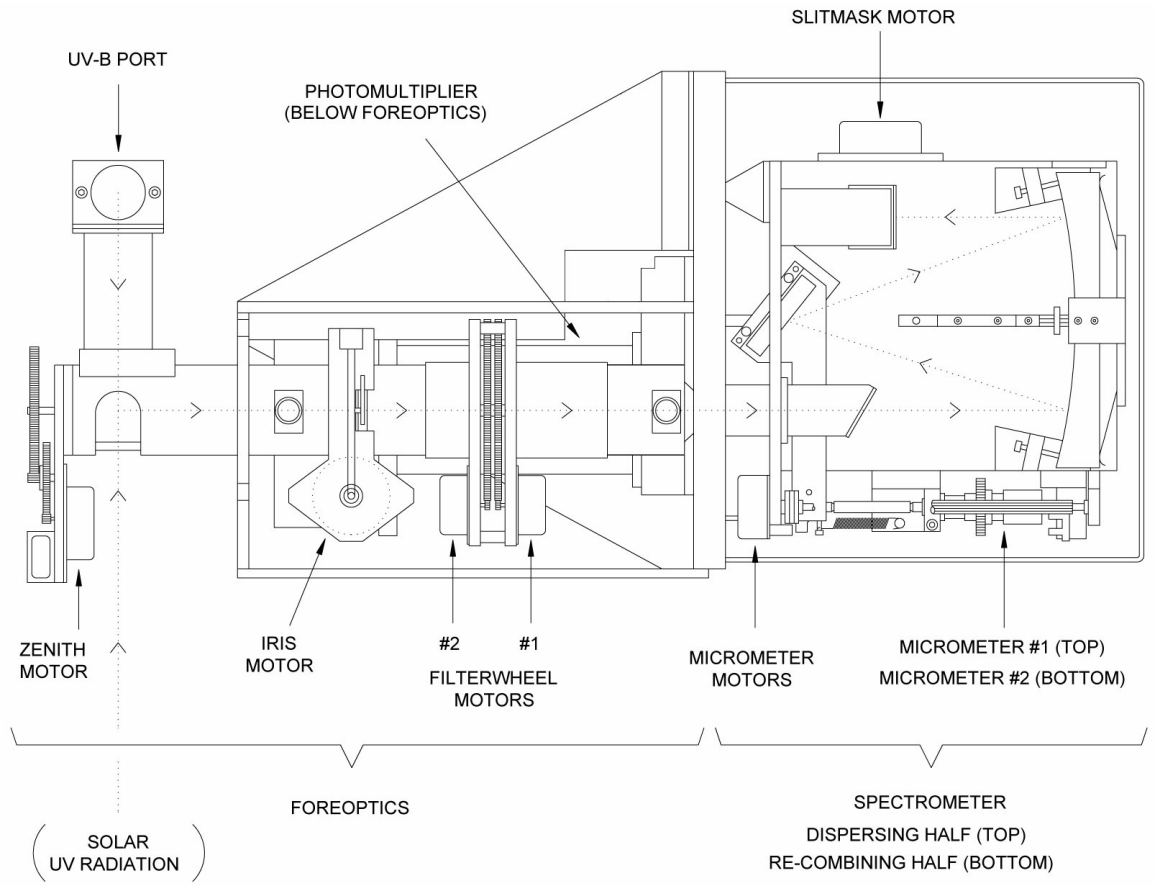


Figure 2.5: Top View of Spectrophotometer

FOREOPTICS Refer to Figure 2.4 and Figure 2.5
The automated system drives stepper motors which control three elements in the foreoptics assembly - the Iris Diaphragm, Filterwheel #1, and Filterwheel #2. The associated driving and sensing electronics are integrated into the Main Electronics board. The Brewer software automatically controls motors once the Configuration File has been appropriately configured. Incoming light is directed through the foreoptics by the director prism [ZP 1], which may be rotated to select light from either the zenith sky, the direct sun, or one of the two calibration lamps. A mercury lamp provides a line source for wavelength calibration of the spectrometer, while a quartz-halogen lamp provides a well regulated light source so that the relative spectral response of the spectrometer may be monitored. Elements in the foreoptics provide adjustment for field-of-view, neutral-density attenuation, ground-quartz diffusion, and selection of film polarizers.

Iris Diaphragm Assembly
An iris diaphragm [IR 1] is mounted in the foreoptics at the ultraviolet focus of a plano-convex lens [LE 2]. This lens focuses ultraviolet objects at infinite distance onto the plane of the iris. A lever arm which protrudes through the wall of the foreoptic tube controls the iris. At one limit of the lever arm the iris aperture is 5mm (iris closed), while at the other limit the aperture is approximately 15mm (iris open). The lever is actuated by the iris stepper motor.

When the instrument is aligned to view sunlight, an image of the sun is focused at the centre of the iris. With the iris closed, about three solar diameters of skylight around the sun pass through the iris aperture into the spectrometer. With the iris open, about 10° of skylight enters the spectrometer.
On the spectrometer side of the iris there is another plano-convex lens [LE 3]. This lens is positioned such that its focal point is in the plane of the iris. Light passing through the iris aperture is therefore collimated along the optical axis.
Lenses [LE 2, LE 3] in the iris-diaphragm assembly are mounted with their plane side facing the iris.

Filterwheels
Filterwheels [FW 1, FW 2] are mounted in a filter-wheel housing. Each wheel has six 25.4mm diameter holes spaced at 60 degree intervals. Each hole can be selected to intersect the optical axis by rotating its filterwheel. The filterwheels are rotated by two microprocessor controlled motors.
FW #1 contains one open hole (#3), two film polarizers (#0 and #5), a ground-quartz disk (#1), an opaque blank (#2) and a second ground quartz disk combined with a neutral density filter (#4). The ground-quartz disk is used as a diffuser for direct-sun and lamp measurements. The opaque disk is used for dark count tests. The film polarizer (#0) is used for all zenith sky and Umkehr measurements. This film polarizer is mounted such that its axis is perpedicular to the entrance slit. The second film polarizer (#5) is mounted such that its axis is parallel to the entrance slit. It is presently used only for specialized research purposes. The open position (#3) is used for moon and UV observations. The second ground quartz / N.D. filter is used for NO_2 operation on MKIV type Brewers.

FW #2 contains an open hole (#0) and five neutral-density filters providing ND=0.5, 1.0, 1.5, 2.0 and 2.5 attenuation (#1 through 5). This filterwheel is used to automatically adjust the light level entering the spectrometer.
[AP 1], an 11.18mm fixed aperture located on the spectrometer side of the filterwheel housing limits the field-of-view of the spectrometer to f/6.
Both Filterwheels have black markings which are visible through the viewing window, and which indicate which FW position the software thinks the FW has been set to.

Foreoptic Viewing Ports
There are two viewing ports along the foreoptic assembly, through which may be viewed the iris diaphragm and any images which are focused onto it, and the entrance slit.
At the bottom of each viewing port is a glass right-angle prism [VP 1, VP 2] mounted inside the foreoptic tubing. The prisms are aligned so that the object to be viewed (iris or entrance slit) appears centred in the viewing port. A plano-convex glass lens [VL 1, VL 2] is placed in each viewing tube to magnify the image.

Rear Fore-Optics.
A plano convex lens [LE-4], whose plane suface faces the entrance slit of the spectrometers focuses the collimated ultraviolet light onto the entrance slit of the first (dispersion) spectrometer.

SPECTROMETERS
The purpose of the spectrometers optical subassembly is to accept light through the entrance slit and disperse it into a high-quality spectrum along the exit-slit focal plane. The spectrometers are modified Ebert types with focal length 16 cm, and aperture ratio f/6.
Six exit slits are positioned along the exit focal plane at the Ozone operating wavelengths - 303.2 nm (302.1 nm for mercury-wavelength calibration), 306.3 nm, 310.1 nm, 313.5 nm, 316.8 nm and 320.1 nm with 0.6 nm resolution. Wavelength is adjusted by rotating the gratings with stepper motors which drive micrometers acting on lever arms. The wavelength-calibration procedure is capable of measuring the wavelength setting with a precision of 0.0001 nm, and of controlling the wavelength setting to 0.006 nm.
Between the spectrometers is a cylindrical mask which exposes only one wavelength slit at a time. The mask is positioned by a stepper motor which cycles through all five operating wavelengths, approximately once per second.

Spectrometers Detailed Description
Light enters the entrance slit and passes through a tilted lens [LE 5] which corrects for the coma and astigmatic aberrations inherent in an Ebert system. In the first spectrometer the light is collimated by a spherical mirror onto a diffraction grating where it is dispersed. A second mirror reflection focuses the spectrum onto the focal plane of a slotted cylindrical slit mask positioned at the entrance of the second spectrometer. Following wavelength selection by the slit mask, the light passes through the second spectrometer where it is recombined and directed onto the exit slit plane. Six exit slits are located along the focal plane at the appropriate wavelength positions.

Entrance and Exit Slit Plates
The entrance slit and six exit slits [ES 1, EX 1] are laser-etched into 0.1-mm-thick disks of hard shim steel. One of the six exit slits (slit #0) is used for wavelength calibration against the 302-nm group of mercury lines; the other five are for intensity measurements and are nominally set at 306.3, 310.1, 313.5, 316.8, and 320.1 nm. The dimensions for the entrance and exit slits are listed in the Selected Parts List.
Both slit plates are positioned on their respective housings by locating pins which orient the slit axis to within 0.1°. Both plates are blackened to minimize light reflections.

Correction Lens
The correction lens [LE 5] has a convex-cylindrical surface (radius 170.0 mm) and a concave-spherical surface (radius 230.0 mm).
Both surfaces are coated with a layer of magnesium fluoride to minimize reflectance at 315.0 nm for an incidence angle of 29°. The lens is mounted in the entrance-slit housing at an angle of 29° to the optical axis with the concave-spherical surface facing the entrance slit. The axis of the cylindrical surface is positioned in the horizontal plane to within 1°.

Spherical Mirrors
The spherical mirrors [SM 1 & SM 2] each have a 324 mm radius-of-curvature. The spherical surfaces are ground from rectangular pyrex blanks. The surfaces are polished, coated with aluminum, and then coated with magnesium fluoride to maximize reflection at 315.0 nm.
Spring-loaded mounts secure the spherical surfaces of the mirrors against three adjustment screws which are normal to the spherical surfaces in the horizontal plane of the spectrometers. The mirrors are allowed to move on a spherical surface defined by the three adjustment screws, up to a limit of 0.25 mm in the horizontal and vertical. Nylon screws prevent the mirrors from moving beyond this limit.

Diffraction Gratings
The diffraction gratings [GR 1 & GR 2] are 3600 line / mm holographic plane-reflectance types, operated in the first order. The gratings have optimum efficiency over the range 225 to 450 nm in the first order.
The gratings are secured with high-quality adhesive to three small blocks which provide kinematic mounts, as well as fine adjustment for rotation of the gratings about the two axes perpendicular to the grating grooves. The three blocks are thus part of the grating and are the basis of point, slot, and plane mounts which allows adjustment by three screws fixed in the grating-mount plates. These plates are suspended on a set of cross-springs which constrain the gratings to rotate in the vertical axis (the axis parallel to the grating grooves). The cross-spring suspension acts as a frictionless bearing. Rotation of the gratings is controlled by two micrometers acting at the end of lever arms such that a 0.03 mm adjustment of the micrometers represents approximately a 0.1 nm wavelength change at the exit-slit plane.

Micrometers
Metric micrometer heads clamped to the spectrometer frame are used to adjust the grating rotation for each half of the spectrometer. Micrometer #1 adjusts the grating in the dispersing half (top) and Micrometer #2 adjusts the grating in the recombining half (bottom). The micrometer shafts are ground to 60 degree cones which insert into bearings at one end of floating pushrods. A conical

depression with a tetrahedral corner at the other end of the pushrods locates a 60-degree cone mounted on the end of the grating lever arms. The pushrods are secured between the micrometer shafts and lever arms by tension springs. The material of the pushrods has been selected to minimize differential temperature effects.
The micrometers are rotated by stepper motors . The motors drive two 10-tooth gears which are kinematically linked to 60-tooth gears on the micrometer shafts. The drive shafts are coupled to the motor shafts with universal joints
One motor step represents 0.006 nm on the exit-slit plane. Backlash of the micrometers and cross-spring bearing systems have been measured at 0.002 nm. The temperature range of operation for the stepper motors and micrometer adjustment is -16° to +40°C.

Slit Mask Assembly

Refer to Table 2.4 and Figure 2.6
Located between the two spectrometers is a slotted cylindrical mask which may be located in one of eight positions Six of the eight positions allow light to enter one of the six exit slits. The second mask position blocks light from all slits so that a dark count measurement can be made. The eighth mask position exposes two of the exit slits so that the dead time of the photon counting system may be determined. The correspondence between slit mask position and selected wavelength is summarized in Table 2-4.
The axis of the cylinder is attached to the shaft of a stepper motor. The mask is aligned with the exit slits by adjusting the vertical position of the motor and adjusting the horizontal position of the cylinder on the motor shaft.
By rotating the slit mask, each of the mask slots aligns with a corresponding slit in the exit plane, effectively selecting a single wavelength. During an HG test the first slot in the slit mask aligns with the Hg calibration slit in the exit plane.

Table 2.4: slit mask position vs nominal wavelength

Slit Mask Position	UV Wavelength Setting (nm)
0	Hg Slit: 303.2nm (Cal=302.1)
1	Dark Count: --------
2	Wavelength 1: 306.3
3	Wavelength 2: 310.1
4	Wavelength 3: 313.5
5	Wavelength 4: 316.8
6	Wavelength 5: 320.1
7	Wavelength 2 & 4 for Deadtime Test

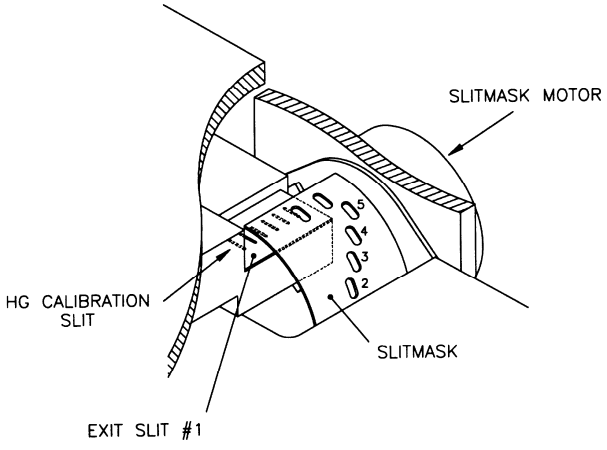


Figure 2.6: Slit Mask Assembly.

Photomultiplier Detector (PMT)
Light passing through the exit slits is collected on the cathode of a low-noise PMT detector [PM 1]. The photon pulses are amplified, discriminated, and divided by 4, before being transmitted to a counter. The resulting photon count is registered in one of six wavelength channels.
Radiation through the exit slits is focused onto the cathode of the PMT by a 38.1 mm focal-length quartz Fabry lens [LE 6].
The cathode of the PMT is located at the ultraviolet focus of the Fabry lens. The spacing between the lens and the PMT takes into account the apparent change in focal length due to the presence of the filters. The PMT is enclosed in a magnetic shield which is maintained at cathode potential (approximately -1300 V) to minimize dark noise. The PMT and its shield are spring-loaded against a teflon ring which locates the cathode at the center-of-focus of the Fabry lens and also insulates the magnetic shield from the PMT housing.
The housing has been designed to allow access to the photon amplifying and discriminating circuitry without disturbing the optics.

Electronics
The Brewer Spectrophotometer contains its own microprocessor board, an 8051 based microprocessor, which controls all internal instrument operations. Specifically, the microprocessor is responsible for:

- positioning the diffraction gratings - the microprocessor controls stepper motors which drive micrometers connected by lever arms to rotating gratings.
- positioning the slit mask to allow light to pass through one of six exit-plane slits to the photomultiplier: this mask is driven by a second microprocessor-controlled stepper motor.
- synchronizing the photon-count circuitry with the movement of the slit mask.
- turning the halogen and mercury calibration lamps on and off.
- reading optical position sensors.
- reading analog monitor voltages.
- moving motors to track the sun.
- moving neutral density, diffusing, and polarizing filters into the optical path.
- opening and closing a field-of-view defining iris.
- provides an RS-422C communications link to an external computer.

The microprocessor is programmed to accept commands from the external Computer, execute the commands, and return results to the Computer. An IBM compatible computer is used as the control console to facilitate programmed command sequencing as well as automatic data logging and processing. Raw data is recorded on hard disk drive, and real-time results may be printed on hard copy or printed to disk for later printing.

The major electronic subsystems of the instrument are:

- Main power supply.
- Main Electronics board - carries control program Flash EPROMs, and a serial communications interface which runs at 1200 baud (bits per second) and provides the following functions:
- Input/Output Interface - on/off control of the calibration lamps, drives the wavelengh-micrometer stepper motor and slit mask stepper motor.
- Photon Counter - accumulates the amplified and scaled photon counts from the Pulse Amplifier, and transfers these counts to the microprocessor.
- Clock-Calendar - a real-time clock / calendar which, with the RAM, has battery protection.
- Analog-to-Digital (A/D) conversion - 24 single-ended, 10-bit A/D channels for monitoring instrument voltages, currents, temperatures, and moisture.

- Pulse Amplifier - mounted in close proximity to the photomultiplier, amplifies and scales the photon-pulse signal from the photomultiplier, and transmits the conditioned photon signal to the Photon Counter
- Lamp Control board - provides constant current control of the two test lamps in the instrument. It also provides monitor information such as lamp voltage and current which is sent to the A/D converter of the Main Electronics Board.
- High Voltage Control module - contains the high voltage supply and control circuitry as one complete module. It also provides a monitor signal to indicate the level of the high voltage and has an electrically adjustable potentiometer to allow for automated high voltage testing.

ULTRA VIOLET DOME ASSEMBLY

Refer to Figure 2.3
The UV Dome Assembly is an optical assembly which enables the Brewer to measure global UV-B, and portions of UV-A and UV-C, using a thin disc of teflon as a cosine collector. The disc is mounted on top of the instrument under a 5-cm diameter quartz dome, and is thus exposed to the global UV irradiance. Beneath the disc is a fixed reflecting prism which is located such that the disc is in the spectrometer field-of-view when the zenith prism is set for a zenith angle of –90° .
Figure 2-3 shows an end view of the foreoptics with the UV subassembly in place.

2.2 SOLAR TRACKING

Within the Brewer software is an Ephemeris algorithm which calculates the azimuth and zenith angles of both the Sun and the Moon as seen from the current location. Data required for this calculation includes the geographic co-ordinates of the site, the GMT time, and GMT date. These angles are further processed by the software, and positioning commands are sent to the Zenith Drive system, and to the Azumith Tracker.

2.2.1 Zenith Positioning System

The Zenith positioning system is attached to the front end of the Foreoptics, and was described in detail in Section 2.1.1.

2.2.2 Azimuth Positioning System

Refer to Figure 3.3 and Figure 5.2
The Azimuth Tracker is an all-weather positioning pedestal comprised of a weatherproof chassis which houses a stepper motor, drive electronics, and a gearing mechanism. The tracker chassis is mounted on a Tripod assembly and is levelled by means of adjustments on each tripod leg. Between the Spectrophotometer and the Tracker is a control cable which carries positioning commands from the Brewer electronics. The positioning commands are input to a motor driver, which provides drive for a stepper motor. As the motor rotates, it turns a stainless steel vertical shaft which, in a friction contact, rotates an aluminum plate fixed to the rotational body of the tracker. The Tracker is fitted with an optical sensor which is used as a reference point, and a ‘Safety Switch’ which removes power to the motor in the event that a failure occurs in the reference sensing system. The Tracker is fitted with its own power supply and power switch.

Table 2.5 Specifications for the Azimuth Tracker

Resolution	±0.02°.
Accuracy (24 hours)	± 0.2°
Max. slew rate	3.91° /sec
Max. angular excursion	-60° to +420°
Payload capabilities: Max. static torque Max. balanced weight	 14.9 Nm 50 kg
Operating temperature range	-40° to +40°C
Dimensions Chassis Enclosure: Height:	 30.5 by 30.5 by 35.6 cm 91.4 cm, with tripod 45.7 cm (18 inch) without tripod
Power requirements:	120 V AC 60 Hz @ 0.5 A 240 V AC 50 Hz @ 0.25 A

2.3 COMPUTER EQUIPMENT

The Brewer Spectrophotometer is operated by GWBasic software. This limits the amount of computer platforms suitable for operation.

Reliable PC platforms for Brewer operation are:

- DOS based computers
- Windows 3.1
- Windows 95
- Windows XP
- and in a number of cases also with Windows 98.

It is important for the computer to have at least one RS-232 serial communication port.

3 BREWER SYSTEM SETUP

Prior to accepting a shipment from the carrier, the containers should be inspected for damage. If any dents or major scratches, cuts, etc. are evident, a damage claim should be filed with the carrier. Only after incoming inspection and operational tests of the Brewer are successfully completed, should the shipment be accepted.

These instruction lead an installer through the Setup of a Brewer Spectrometer.

Since Brewers are usually operated at some distance from the Computer Equipment, (probably out of doors, and out of site of the Computer room), the setup will be done in two stages. The Brewer will first be set up and tested in close proximity to the Computer, and then it will be installed at its final location.

Before starting, ensure that correct AC voltage is availabe as per the diagram in Figure 3.1 and Table 3.1.

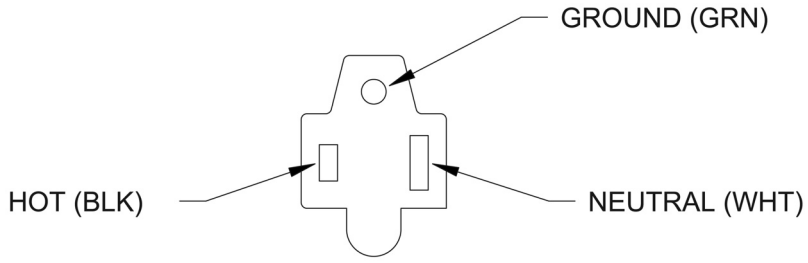


Figure 3.1: AC Power Voltages

Table 3.1 AC Power Connector Voltages

measured voltages between	230VAC installations	120VAC installations
ground & neutral	**0 VAC**	**0 VAC**
ground & hot	**240 VAC**	**120 VAC**
neutral & hot	**240 VAC**	**120 VAC**

REFER TO FIGURES 3.2 and 3.3 FOR THE FOLLOWING SETUP

The complete Brewer Spectrometer system consists of the following:

- a Spectrophotometer
- an Azimuth Tracker
- a Tripod Stand
- a Control and Data Logging Computer (optionally from KIPP & ZONEN)
- a set of Interconnect Cables
- a set of Basic Spare Parts
- a set of Optional Spare Parts
- other Optional parts

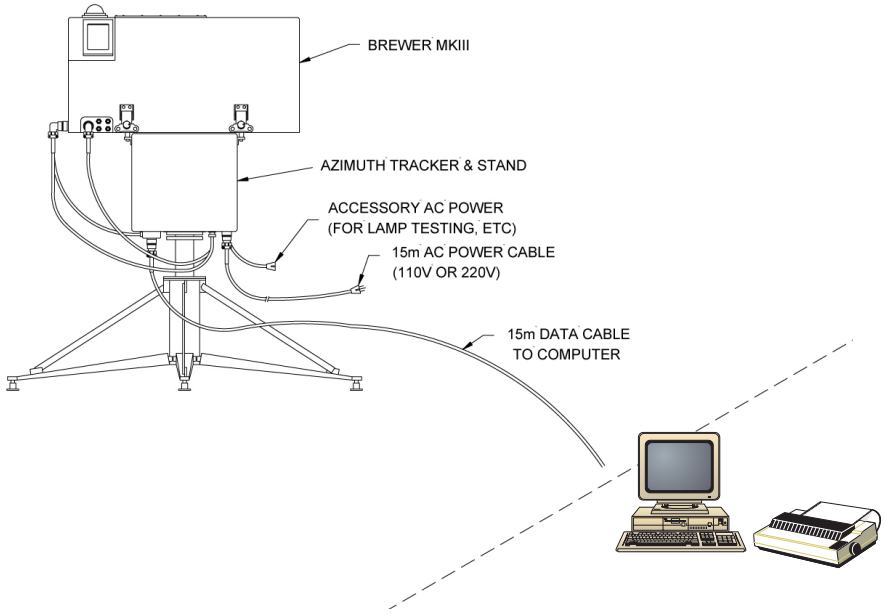


Figure 3.2 Brewer Equipment Setup

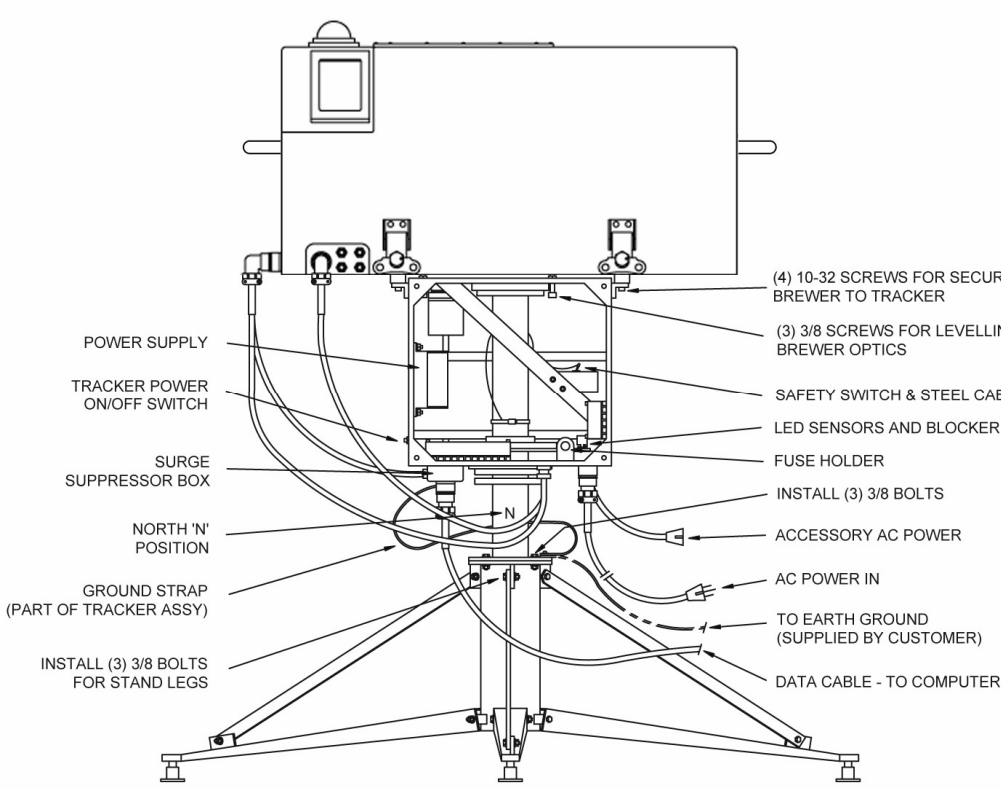


Figure 3.3: Brewer Spectrophotometer / Tracker / Tripod

3.1 SPECTROPHOTOMETER UNPACKING AND SETUP

1. Open the Brewer crate and inspect the contents - at least the following items will be found:
   - Brewer Spectrophotometer
     - AC Power Cable, BA-W12
     - Data Communications Cable, BA-W68
     - RS422/RS232 Data Set and AC Power Converter
     - Manuals (Operator's, Service, Final Test Record)
     - Basic Spares Kit, BA-C112
     - Brewer System Diskettes (three diskettes)
2. Remove the Brewer Cover by unlatching the four latches and lifting the cover off the Base.
3. Remove the protective foam on top of the optical assembly and from under the black sprectrometer cover. Inspect the Brewer for loose or broken parts, or disconnected cables. It is recommended to keep the foam for if the instrument is ever to be shipped again.
4. Connect the AC Power Cable to the appropriate connector as per the markings on the Brewer Cover, plug the other end into a source of AC power, and press the Power Switch.
5. Observe that the green Power Lamp illuminates, and that activity occurs as the Brewer Motors initialize.
6. Place a few packages of active desiccant (Silica Gel) inside the Brewer and replace the Brewer Cover.
7. Turn off the Brewer Power Switch and disconnect the power cable.

3.2 TRIPOD UNPACKING AND SETUP

Refer to Figure 3.4.

1. Open the Tripod crate and locate the following:
   - Installation instructions floor stand
   - Three Support Legs
   - Three support bars
   - Upper and lower flange
   - Bag with bolts and nuts
   - Bag with Tie-Down kit (this kit will be used in the final assembly, refer to figure 3.6)
2. Attach the three legs to eachother with (12 M6 x 16 cap screws, lock washers and flat washers (do NOT tighten the screws).
3. Assemble the upper flange to the three legs with (6) M6 x 16 cap screws, lock washers and flat washers (do NOT tighten the screws).
4. Assemble the lower flange to the three legs with (6) M6 x 16 cap screws, lock washers and flat washers (do NOT tighten the screws).
5. Attach the three cross braces to the three legs with (3) M6 x 120 cap screws, lock washers and flat washers (do NOT tighten the screws).
6. Tighten the 27 cap screws using the provided hex key.
7. Place the stand on a flat mounting surface (recommended surface: concrete pad).
8. Install the Tie-Down kit. Note: the customer has to install an eye bolt (with attachment "ring" or "hook") in the pad.
9. Tighten the M8 nut of the Tie-Down kit with max. 5 Nm (44 in.lbs).

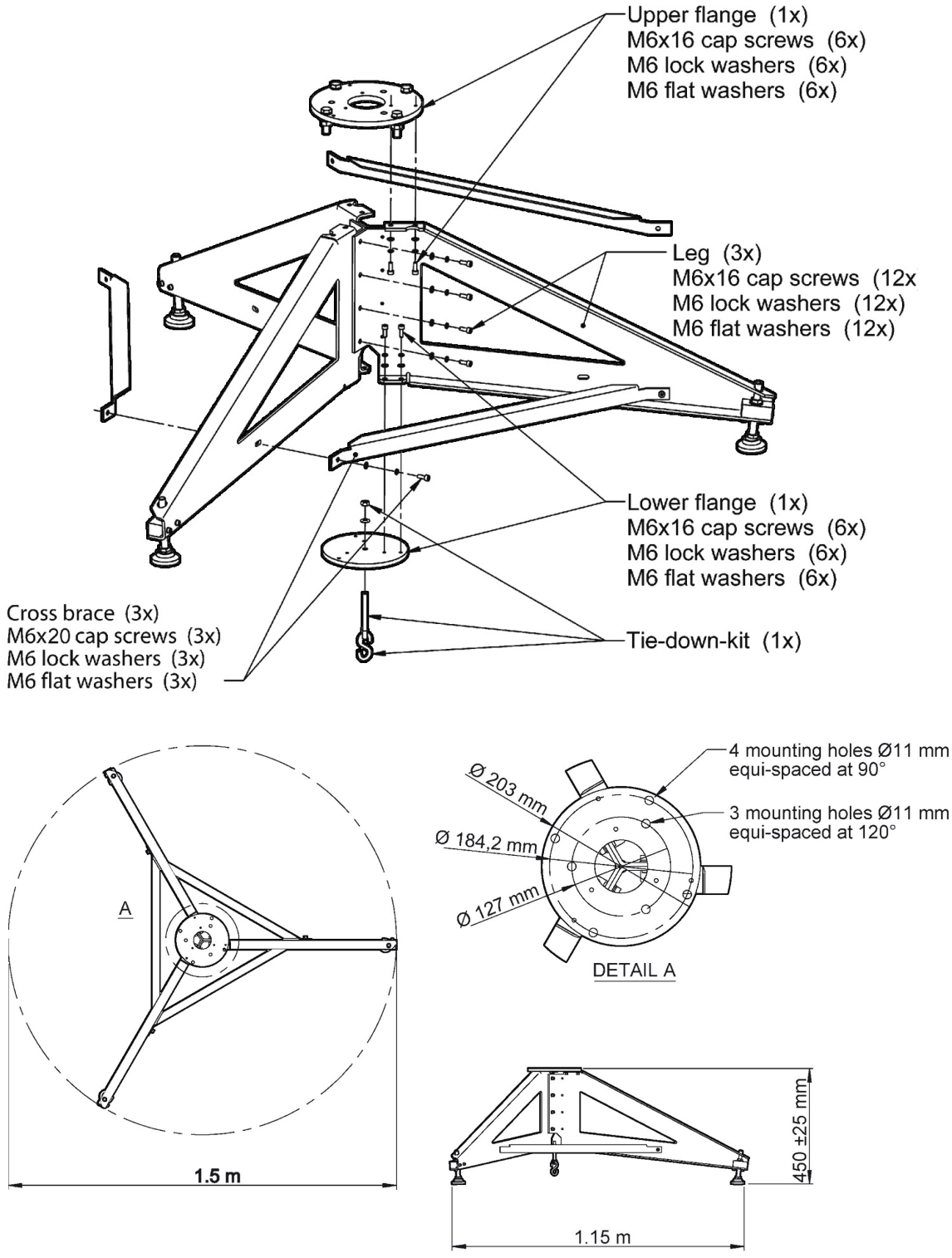


Figure 3.4: Brewer Spectrophotometer Tripod.

3.3 AZIMUTH TRACKER UNPACKING AND SETUP

Refer to Figure 3.3.

1. Open the Azimuth Tracker box, remove the Tracker, and inspect it for damage.
2. Mount the Tracker onto the Tripod and secure it with the bolts provided.
3. Remove the front and rear covers from the Tracker, and note the spare fuses and mounting bolts taped to the inside wall of the Tracker.
4. Locate the Safety Switch, which can be found inside the Tracker housing, mounted on the diagonal support bar.
   The purpose of the Safety Switch is to prevent damage to the Power and Communications Cables by removing power from the drive motor in the event that the Tracker attempts to rotate too far.
   This Switch is activated by a steel cable and a nylon cord which tighten as the Tracker rotates.
5. Check the Safety Switch as follows, taking care not to break the nylon cord:
   Rotate the Tracker slowly until the black blocking mechanism mounted to the large circular disk is positioned within the Sensor, which is mounted beneath the Safety Switch, This is the "reference" position of the Tracker.
   Ensure that the Tracker will rotate a full 360° in a CCW direction, and 90° in a CW direction from this reference position without activating the Safety Switch or breaking the nylon string.
   Leave the Tracker such that the blocker is a few degrees CCW from the sensor.
6. Connect the AC Power Cable to the 120V / 230V connector on the underside of the Tracker (the green Power Indicator will remain off) - if it comes on, push the Power Switch to turn the power indicator lamp off.
7. Rotate the Tracker a few degrees and note that it is relatively easy to turn when power is off.
8. Press the Tracker Power Switch to turn power ON, and observe that the green Power Indicator Illuminates.
9. Attempt to rotate the Tracker again, and note that it is much more difficult to turn with holding torque on the motor.
10. Activate the Safety Switch manually by pushing the toggle to the right (BE CAREFUL, AS THERE IS 120V OR 230V INSIDE THE TRACKER HOUSING), and note that the Power Indicator remains illuminated, but now the Tracker turns easily again.
11. Deactivate the Safety Switch, and turn the Tracker Power Switch OFF.

3.4 MOUNTING THE BREWER

Refer to Figure 3.3.

1. Place the Brewer on top of the Tracker. The Brewer Power Switch should be directly above the Tracker Power Switch, and the three bolts protruding from the top of the Tracker mate to the three tapered holes in the bottom of the Brewer - these three bolts form a kinematic mount for the Brewer Optical Assembly.
2. Secure the Brewer to the four Tracker mounting fixings with the bolts provided in the Basic Spares Kit - there are spare bolts taped to the inside wall of the Tracker.
3. When securing the Brewer to the Tracker, start the bolts by hand to ensure that no cross-threading occurs before using the Allen Wrench included in the Basic Spares Kit to do the

final tightening. Care must be taken not to overtighten the bolts as the rubber feet may be damaged.

4. Connect the AC Power Cable to the 120V/230V connector on the underside of the Tracker, and connect the Data Communications Cable to the Surge Suppressor Box assembly mounted to the underside of the Tracker.
   Always connect the power cables first, before connecting the communication cables.
5. Connect the remaining cables from the Tracker to appropriate connectors on the Brewer – Note that each cable / connector combination is unique, which makes it difficult, but not impossible, to mate the cables incorrectly.
6. Turn ON the Tracker Power Switch and the Brewer Power Switch - both Green Power indicators will come on, the Brewer will go through an initialization sequence once again, and the Tracker will be difficult to turn by hand.
7. Turn the Brewer and the Tracker Power Switches OFF, and remove the communications cable from the Tracker.

3.5 BREWER OPERATING SOFTWARE

Brewer Operating Software is provided on three 3.5” diskettes, with part numbers BA-E116, BA-E118, and BA-U07, and will be installed in step 2. below.

Disk BA-E116 contains files in directories \ , \DOS , \BREWER, \UTIL, \UV-LAMP.

\ directory -- these are batch files, those with .BA_ extensions to be used as examples, and those with .BAT extensions to be used to launch the BREWER and the NOBREWER software.

\DOS directory -- these files are required to run the Brewer software, and some of its ‘DOS’ functions.

\BREWER directory -- these files contain the MAIN Brewer operating program and all of the routuines and data files necessary to control all of the Brewer command functions.

\UTIL directory -- contains some infrequently used utilities.

\UV-LAMP directory -- contains utilities specific to UV, such as for the generation of new UV response files.

Disk BA-E118 contains a number of directories containing routines developed by various Brewer users for specific applications. These routines are not supported by KIPP & ZONEN.

Disk BA-U07 contains files in directory \BDATA and subdirectory \BDATA\NNN (where NNN is the Brewer number.)

\BDATA directory -- these files contain data collected during the testing of the instrument.

\BDATA\NNN -- these files contain firmware and software configuration information specific to the Brewer whose Number (NNN) appears on the Disk identifier, as well as the utility used to load firmware.

3.6 COMPUTER SETUP

This instruction assumes that KIPP & ZONEN has NOT supplied the Computer equipment. If KIPP & ZONEN has supplied the Computer, then many of the following steps will have already been completed, and need only be confirmed at this time.

1. Set up and interconnect the Computer as per the Manufacturer’s instructions, and confirm that the Brewer and Computer communicate by simply start the Brewer software and wait for the main menu to appear.

   Plug the Computer power cord into an AC Power Bar that has at least two additional outlets, as they will be required in a later step.

2. Make copies of the CD-ROM that came with the Brewer and use the copies in the following steps.

3. Inspect the contents of the CD-ROM and copy the contents into directories of the same names on the C: drive of the Control Computer.

4. Using the supplied AUTOEXEC.BA_ as a guide, and use a text editor to add pathing to the AUTOEXEC.BAT file on the computer to include at least :

   C:\;C:\DOS;C:\BREWER;C:\BDATA

5. Use a text editor to display the OP_ST.NNN file in the C:\BDATA\NNN (NNN is the Brewer Number). Note the third entry in the file - it will be a file name of the form ICFJJJYY.nnn.

6. Using a text editor again, open the “ICF” file as found in step 5.

   Line item #24 (following MKIII entry) is the number of the COM: port to be used for communications with the Brewer - the number shown (1 or 2) must match the Computer COM: port number which will be used in this installation, and should be changed if it is not correct - - note that 1 and 2 are the only valid entries.

7. Go to the C:\Brewer directory, and with the text editor, open the file OP_ST.FIL and edit this file such that the Brewer number to be installed matches the first entry in the file.

8. Configure the AUTOEXEC.BAT file (for DOS), or the Startup Menu (for Windows based systems), if it is desired to have the Brewer restart automatically following a power failure.

9. Test the Software and COM Port:

   - connect the appropriate wires of the Communications Cable, (marked with tags) to the RS422/RS232 Data Set .
   - plug the output of the Data Set Power Adapter into the Data Set, and then plug the Adapter into the AC Power Bar - the AC Power indicator on the Data Set will illuminate.
   - plug the Data Set into the appropriate COM: port of the Computer, using an adapter, if necessary - see step 6 above.
   - launch the Brewer program by running the BREWER.BAT file through Windows, or by typing “BREWER” at a DOS prompt - at this point activity will appear on the computer screen, but for this test, only the lights on the Data Set need to be monitored.
   - the power indicator will remain on, and in less than a minute, the TD indicator of the Data Set will illuminate for a few seconds, indicating that the COM: Port is correct, and that the computer has sent a RESET message.

10. Interrupt the Brewer program by pressing Ctrl+Break, and at the GWBASIC prompt (_), type “SYSTEM” (and Enter) - this will return the computer to where it was prior to the Brewer program being launched.
11. Turn off Computer power.

3.7 BREWER / COMPUTER INTEGRATION

This section assumes that the Brewer, Tracker, and Computer Equipment have been individually set up and tested for startup operation.

1. Connect the Communications Cable to the Azimuth Tracker connector, and connect the Data Set to the Computer COM: port.
2. Attach the Green wire on the Computer end of the Communications Cable to a ground point on the Computer (use a screw on the rear panel of the Computer).
3. Plug the AC Power Cable from the Azimuth Tracker into same Power Bar as are plugged the Computer and the Data Set power. Ensure that the other end of the power cable is plugged into the connector under the Tracker, and that the three cables are connected between the Tracker and the Brewer.
4. Turn Brewer and Tracker power ON.

   - Brewer and Tracker lights will illuminate

   - activity will occur inside the Brewer indicating an initialization is in progress.

5. Turn Computer equipment power ON, and launch the Brewer program.

- the “Brewer” screen will appear, and a number of files will be “merged”
- the FR routine will load and the Micrometers will RESET.
- the Data Set will indicate communications are occuring by periodic flashes of the TX and RD lights.
- following initialization, the Date and Time and Brewer Site information will be read and the Tracker will move to a calculated Solar Azimuth - note that this azimuth will be incorrect if the Date, Time, or Site Co-Ordinates are incorrect.
- when the Initialization and reset have completed, the MAIN MENU will appear on the Computer screen, indicating that the Brewer is ready to accept commands.

6. Test the Printer (only if used)

At the Command Prompt, cm-> of the Brewer Menu Screen, type PNTE, and press “Enter” to issue the commands.

These commands will turn the Printer on (PN) and will cause the temperature (TE) of one of the Thermistors in the Brewer to be printed - moisture will also be printed if the Brewer is fitted with the Moisture option.

At this point the Brewer Main Menu will appear on the Computer Screen and the Software will be ready to accept Commands as seen by the blinking cursor to the right of the prompt, cm->. See Figure 3.5.

This is a good time to set the Date, the Time, and to enter Site Information.

Read about the DA, TI, LF, and LL commands in the Section 4 of this Manual.

If accurate information is not availabe to input at this time, a “best guess” should be used so as not to delay testing.

Information required:

- GMT Time, accurate to within 20 seconds
- GMT Date
- Site Name
- Site Latitude - in degrees, to two decimal accuracy
  - use + for Northern Hemisphere
- Site Longitude - in degrees, to two decimal accuracy
  - use + for Western Hemisphere
- mean Barometric Pressure of the Site, in mBar

7. TIME SET: At the cm-> prompt type TI, and press Enter. The software wil prompt for the GMT time and for verification.

8. DATE SET: At the cm-> prompt type DA, and press Enter. The software will prompt for the date and for verification

9. LOCATION EDIT: At the cm-> prompt type LF, and press Enter.

- a list of some existing Brewer Locations will scroll on the screen
- as a new entry, enter the current Site information, using other entries as a guide, and follow screen prompts to save and exit the edited file.

10. SELECTING SITE : At the cm-> prompt type LL, and press Enter.
    - a list of Site Names will appear.
    - type the number of the desired Site and press 'Enter' twice.
    - the Tracker position will update according to the information entered in step 9, and the new site name will appear on the Main Menu screen.
11. CONFIRMATION: If the Tripod Stand leg that is adjacent to the " N " marking on the lower Tracker flange is pointing to Geographic North, then the Observation Window of the Brewer will be pointing toward the Sun - assuming Date, Time, and site Co-ordinates are correct. It is not of major concern if the Brewer is not pointing accurately at this time, as some other parameters may still need adjustment.
    Note: the newly entered GMT Date and Time are shown on the Computer display.

3.8 MAIN MENU COMPUTER DISPLAY

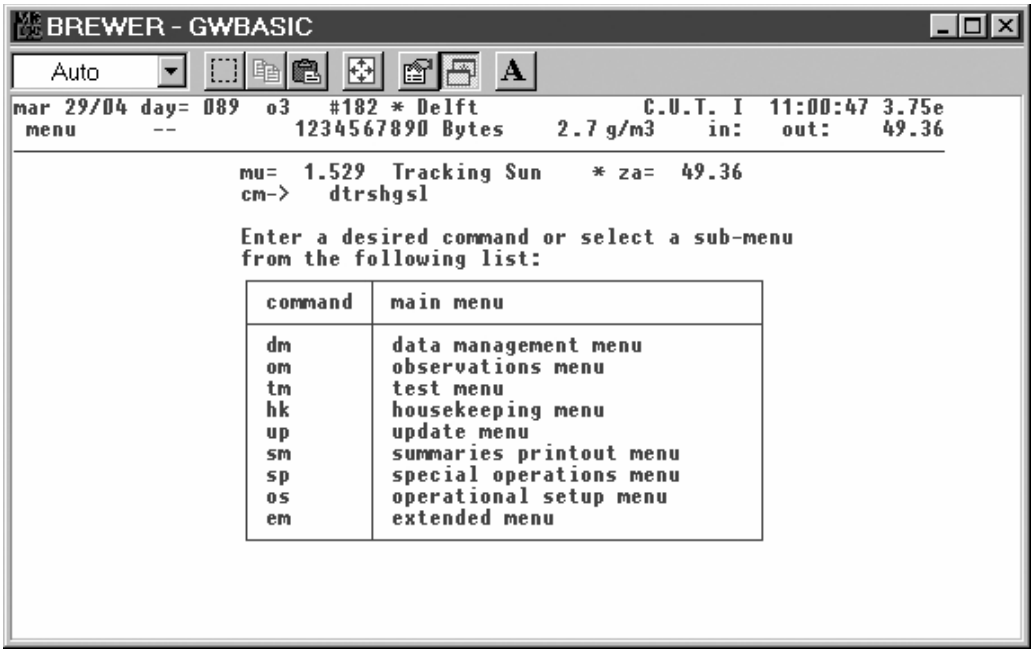

BREWER - GWBASIC
Auto
mar 29/04 day= 089 o3 #182 * Delft C.U.T. I 11:00:47 3.75e
menu -- 1234567890 Bytes 2.7 g/m3 in: out: 49.36
mu= 1.529 Tracking Sun * za= 49.36
cm-> dtrshgsl
Enter a desired command or select a sub-menu
from the following list:
command | main menu
dm | data management menu
om | observations menu
tm | test menu
hk | housekeeping menu
up | update menu
sm | summaries printout menu
sp | special operations menu
os | operational setup menu
em | extended menu

Figure 3.5: Typical Brewer Main Menu Screen

3.9 INITIAL TESTS

A few functional tests should be done prior to the Brewer being moved to the final location. It is assumed that all setup to this point has been successful.
A brief description of each Command is given in the Section 4 of this Manual, and should be read before proceeding.

NOTE that if only one command is issued, it may have to be followed by an "**Enter**" from the keyboard.

Issue each of the following commands in turn, followed by Enter, and wait for the Main Menu to return before going to the next command.

PD: routes all printing to the hard drive
TE: prints temperature and humidity
RL: prints the firmware error log
PO: prints instrument constants
RE: initializes and resets the Brewer
SR: * performs an Azimuth Tracker steps/revolution test
HP: * grating synchronisation
HG: * wavelength calibration (takes about 7 minutes)
RS: * run stop /test (takes about 8 minutes)
SL: * standard lamp test (takes about 8 minutes)
DT: * dead time test (takes about 8 minutes)
AP: * prints A/D monitor values
FR: resets micrometers

Compare the results of the tests marked " * " with those in the FINAL TEST RECORD and consult KIPP & ZONEN if there are any discrepancies or problems noted in the tests.

3.10 FINAL INSTALLATION

If the results of the initial tests are within acceptable tolerances, then the Brewer can be moved to its final location.

1. At the Brewer Main Menu, issue the command, EX, and the Brewer Operating Program will terminate.
2. Turn OFF all Brewer and Computer equipment and remove all interconnecting cables.
3. Route the Power and Data Cables from the Computer to the Brewer final location.
4. Disassemble the Brewer-Tracker-Tripod setup , and move them to the final location.
5 At the final location, place the Tripod on a flat surface such that one leg points approximately toward geographic North.
6. Use the Tripod "tie-down kit" to secure the tripod against movement due to accidental bumping or high winds. See Figure 3.6.

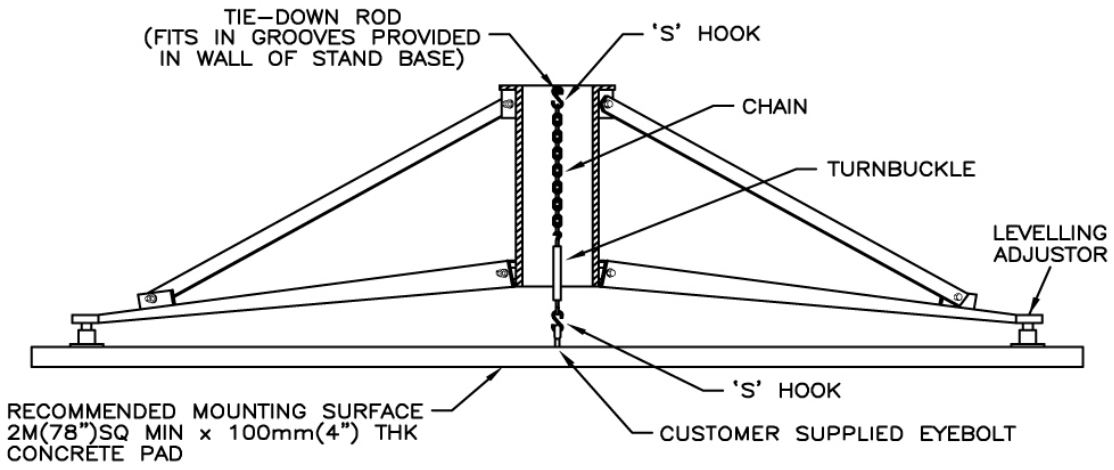


Figure 3.6: Securing the Tripod

7. Mount the Tracker onto the Tripod, orienting it such that the “N” marking on the lower Tracker flange is pointing approximately toward geographic North.
8. Remove Covers from the Tracker, and locate the Safety Switch - monitor the Switch during the following operation so it does not become activated, and the nylon cord does not become broken.
9. Place a spirit level on top of the Tracker and do not move it for the duration of the following levelling operation.
10. Rotate the Tracker slowly while observing the spirit level, being careful not to activate the Safety Switch or break the nylon cord.
    Adjust the three levelling bolts on the Tripod Legs until the Tracker can be rotated a full turn with the bubble in the level remaining constant.
    Note that the bubble does not have to be in the mid-position, so long as it does not change position by any large amount.
11. When the Tracker is level, mount the Brewer , and interconnect all of the cables between the Computer, the Tracker, and the Brewer.
12. In order for the Surge Suppressor circuitry to be effective, the Brewer System must be connected to a good “Earth Ground”.
    The Surge Suppressor is located in an assembly mounted to the underside of the Tracker, and a wire braid connects it to a bolt on the Tracker Flange.
    The “Earth Ground” must be attached to this bolt, and routed under the Tracker such that it does not interfer with the Power Cable or the Communications Cable.
13. Since the Tracker follows the azimuth of the Sun for 24 hours each day, it must rotate in a clockwise direction from 0° to 360°, and then return to 0° in a counterclockwise direction.

    Sufficient slack in Power and Data cables must be left near the Tracker to allow for this movement.
14. Turn Brewer and Tracker power ON and observe that the two Power Indicators illuminate and that the Brewer initializes.
15. Turn the Computer power ON and launch the Brewer program.

    Following Brewer initialization, the Main Menu will appear on the screen.

4 BREWER COMMANDS

4.1 RESERVED KEYS: HOME, DEL, CTRL+BREAK, F KEYS

HOME

This key can be pressed to terminate an observation or operation prematurely. It should only be used if the message " press HOME key to abort " is displayed on the screen.
There may be a delay between the time when the DEL key is pressed, and the Main Menu appears, as some aborted activities take longer to terminate.

DEL

This key is not normally used for routine work. It can be used in special situations to bypass the five-minute warm-up period of the mercury or standard lamps, or to terminate some operations, such as the zeroing of the Azimuth Tracker if no tracker is present.
There may be a delay between the time when the DEL key is presses, and the Main Menu appears as some activity takes longer to abort.

Ctrl+Break

This combination temporarily halts the Brewer Program so that the GW-BASIC operating system may be accessed.

After the CTRL+Break keys have been pressed,

Break in xxxxx
OK

will be seen, there will be full access not only to all GW-BASIC commands, but also to the Brewer Program itself.

There are a number of ways to restart the Brewer program following a CTRL+Break:

- instruct the program to continue by typing “CONTINUE”.
- type “SYSTEM” to abort completely from GWBASIC and re-initiate the Brewer operation by one of the traditional methods.

The menu displays the MU (air-mass) and ZA (solar zenith-angle) which will be continuously updated during the course of the day, as well as the GMT, date, instrument number, location and data bytes available. Pressing the Return key without a command entry causes the Main Menu to reappear.

To issue a command, the appropriate character code is typed, followed by the Enter key.

F Keys

The F keys are configured to automatically write commonly used commands or sets of commands. The F keys can be used at the Brewer command prompt. The enter key must be pressed to start the command string.

F Key	Command Sequence
F1	DS
F2	ZS
F3	ZB
F4	HG
F5	SL
F6	HGSL
F7	DSZS2
F8	HGZC2
F9	HGSLDSZSDS
F10	DTRSHGSL

4.2 BREWER COMMAND SUMMARY

Following is the Command Set of the Brewer Spectrophotometer.

Commands are entered at the command line, **cm->.**
Note that only two character commands are accepted in a 'multiple command' string or in a schedule.

Commands may be entered as a series of single commands; each followed by 'Enter', or as a command string, consisting of a series of commands, and followed by 'Enter' (i.e. pdaphg 'Enter').

One or more '**ENTERs**' (when they are prompted for) is generally required for the execution of a single command, whereas on the entry of multiple commands, the subsequent 'Enters' are automatically performed by the software.

File Name Conventions - JJJ -- indicates a Julian Day.
YY --- indicates a year
nnn -- indicates a Brewer Instrument Number

AP Monitor Voltages Printout
This command prints to the line printer, the monitor screen, or to disc, a number of diagnostics that are continuously available in the Brewer. The diagnostics include power supply voltages, test lamp voltages and currents, temperatures, and Brewer moisture content, if the Brewer includes the "Moisture" option. A full list of AP output values can be found in Appendix A

AS Azimuth Tracker to the Sun
The AS command moves the Azimuth Tracker to the azimuth angle where the Ephemeris has calculated the sun to be for the current location and time. The North Correction from the most recent Siting (see SI command) is applied.

AU Automatic Operation
The AU command results in the Brewer executing a series of commands which are imbedded the AU routine (HP HG DS ZS DS ZS DS ZS B1 UV (or UX)). The sequence continues until interrupted by an operator, or until the sun reaches ZA = 85. At ZA = 85, the system executes the ED command.

AZ Azimuth Tracker Zeroing
The AZ command causes the Azimuth Tracker to return to its zero reference (North) position, and then move the Brewer to the solar azimuth as calculated by the Ephemeris according to the Location, the Time, and the current North Correction, as determined by the most recent Siting (see SI command). See also Appendix F.

B0 Turn off Lamps
B0 ensures that the Standard Lamp and Mercury Lamps are both off.

B1 Mercury Lamp ON
B1 turns on the internal Mercury Calibration Lamp, and is useful in a command sequence (i.e. B1DSHG) where a DS measurement is taken while the Mercury lamp is warming up B1. **Note** that if the HG does not execute for some reason, the lamp may be left on and must be turned off with the B0 command.

B2 Standard Lamp ON
B2 turns on the internal Standard test Lamp and is useful in a command sequence (i.e. B2ZSSL) where the ZS measurement is taken while the Standard Lamp is warming up. **Note** that if the SL does not execute for some reason, the Lamp may be left on and should be turned off with the B0 command.

CF Instrument Constants File Update
CF accesses the Brewer's Instrument Constants File and allows the operator to make changes.
Note that the constants in this file affect the operation and calibration of the instrument, and normally are not changed unless the instrument is undergoing recalibration or has undergone repairs. This command requires operator input, and changes should be made or approved only by qualified personnel. See also Appendix B.

CI Lamp Scan on Slit #1 and Slit #5
CI is used to perform a wavelength scan from 286.5 nm to 366 nm on one of the two internal test lamps. Filter Wheels are set to positions 1 and 0, and the Iris is open. The increment of the scan is user selectable with choices of 1, 2, or 5 Angstrom. Data can be compared with the data contained in the Final Test Record, and is stored in the file CIJJJYY.NNN in the \BDATA directory. A typical command sequence might be B1W1CI, where B1 turns on the HG lamp, W1 produces a 5-minute lamp warm-up delay, and CI executes the wavelength scan.
See Appendix A for the format of the CIJJJYY.NNN file.
The CI command requires operator input.

CO Comments
CO allows the operator to enter a comment (up to 75 characters) into the Brewer data file. This command is useful to record information about a measurement, current weather, sky conditions, and so on.
This command requires operator input.

CS Command Sequence
CS is similar to a command line entry at the cm->__ prompt. The operator may enter a sequence of commands to be executed, followed by an integer which indicates the number of times the sequence is to be repeated.
This command requires operator input.

CY Slitmask Cycles
The default value for slitmask cycling for most observations is 20. The CY command may be used to increase or decrease this number if better statistics, or a faster measurement (with degraded statistics) is desired.
This command requires operator input.

CZ Custom Scan
CZ allows the operator to define a custom scan. Sources may be one of the internal lamps, the UV port, or the quartz window. The scan may be over any wavelength range within the Brewer's UV scan limits, have any wavelength increment, and use any filterwheel combination.
This command requires operator input. Data is stored in a CZJJJYY.nnn file. See also Appendix A.

DA Date Set

The Brewer ephemeris requires GMT (both date and time) for proper operation. Under normal, uninterrupted operation, the computer, and Brewer, dates will change at 00:00:00 UT, and are displayed on the monitor screen. Under some conditions (power failure at 00:00:00 UT), the date may not update, and may have to be corrected manually. The pointing system updates automatically when a new date is entered.
This command requires operator input.

DD Print Data Directory

DD causes a file listing of the Brewer data directory to be sent to the printer. The printer must have been turned on with the PN command.

DDP Print Data Directory

DDP causes a file listing of the Brewer program directory to be routed to the printer. The printer must have been turned on with the PN command.

DDS Print Data Directory to the screen

DDS causes a file listing of the Brewer data directory to be routed to the monitor screen.

DI Disk Recording

DI causes data to be recorded in the directory as specified in the OP_ST.FIL found in the Brewer program directory. Data recording may be turned off if the data disk is nearly full, if the data disk specified is not installed, or if the NR command has been sent. If recording is turned off, the screen will display “DISK TURNED OFF” on the screen in place of the “BYTES” message, and must be turned on with DI. See also the NR command.

DS Direct Sun Ozone Observation

DS results in an O_3 observation being taken using the direct sun as a radiation source. The Brewer Zenith Prism and Azimuth Tracker are oriented toward the sun, the Iris is closed, FW#1 is rotated to the Ground Quartz Disk (position 1), and FW#2 is adjusted for maximum intensity (starting from position 2) without overdriving the PMT detector. Data is recorded on disk and is printed as previously determined by PN, PD, and PF commands.
A DS observation consists of five sets of 20 cycles of the slit mask (a measurement), each cycle taking a reading for 2*0.14 seconds on each wavelength. Intensity data for six wavelengths, and the dark count, is recorded for each of the five measurements.
The Azimuth and Zenith positions are updated after each measurement.
After each measurement O_3 are calculated. After the fifth measurement all data is processed, resulting in a single summary set for the total observation.
As a safety feature to prevent damage to the detector, the measurement may terminate if, as a result of varying cloud conditions, FW#2 has initially been set to a low attenuation value and clouds suddenly move out of the field of view.
A DS measurement takes slightly more than three minutes to complete.
Details of the data as recorded in the raw data (B) file, and the summary data as recorded in the summary (S) file can be found in Appendix A.

DSP Dispersion Test

DSP allows for the collection of data for a dispersion test analysis wherein absorption coefficients, wavelength vs. step number and resolution vs. step number equations for each slit is determined.
This is a command generally reserved for factory use or for use during an instrument recalibration.

DSSUM Direct Sun Data Summary

DSSUM reads the daily Data (B) file and printouts out the summary of the day's DS measurements. An entry is also made to the OZOAVGYY.nnn file. The DSSUM command is usually used as part of the ED command.
See also Appendix .

DT Dead Time Measurement

Dead Time is a measure of how long a photon counting circuit is "dead" (or cannot count a second photon) after a first photon has been detected. This characteristic of counting circuits can lead to counting errors especially at high photon rates if not compensated for. The DT command initiates a test for the measurement of the dead time of the Photon counting circuits of the Brewer. The DT command is normally executed as part of the ED routine and the test results are recorded in the DTOAVG file. Times differences of greater than 5% should be investigated.
The dead time for each instrument is manually record in the Instrument Constants File and can be seen on the PO command printout.
For this test the iris is closed, FW#1 is put to position 1. Measurements are made at high intensities (FW#2=0), and at low intensities (FW#2=1).
See Appendix F and Appendix .

ED End of Day

At the end of each solar day (solar midnight) it is desirable to summarise, sort, and print out the results of the tests and observations taken the previous day. This may be achieved by using the ED command.
The ED routine:

- summarises data into an "S" file (see SUM).
- sorts and prints data from observations and tests (see OZSUM, FMSUM, FZSUM, HGSUM, SLSUM, UVSUM, ZSSUM).
- prints constants and monitored values (see PO, AP).
- executes a series of tests (see HG, SL, DT, RS, SR, RE, FR)

The first command in ED is a print command, which directs the printout to the printer (see PN) or to a disk file (see PD). If the operator wishes to change the printing path, either the ED-PD.RTN or ED-PN.RTN must be copied to ED.RTN.
An operator may run ED at any time. If the Brewer is running in a schedule (see SKC), the ED command is initiated automatically at solar midnight.
See also ED-PD and ED-PN.

ED-PD End of Day, print to disk

ED-PD and ED-PN are the same as the ED command but the operator may easily select the method of printout. In the Brewer program directory, either the ED-PD.RTN or the ED-PN.RTN may be copied to the ED.RTN, resulting in the ED printout being directed to a disk file or to the line printer (see PD and PN commands). See also ED, ED-PN commands.

ED-PN End of Day, print to printer

See ED, ED-PD commands.

END_DAY End of Day (past day)

Command Syntax: END_DAY Feb29/98 or END_DAY 06098
END_Day performs an End of Day on a previous day's data. For the command syntax example: if the raw data file B06098.nnn exists, a Summary file (S06098.nnn) will be created and summary files printed.

FF Form Feed

FF results in a Form Feed on the printer.

FM Focused Moon Observation

FM results in an O_3 observation to be taken with the moon as the radiation source.
The Brewer Zenith Prism and Azimuth Tracker are oriented to the moon, the Iris is opened, FW#1 is rotated to the position 3, and FW#2 is adjusted for maximum intensity, starting at position 2.
Data is recorded on disk and is printed as previously determined by PN, PD, and PF commands. An FM observation consists of five sets of 80 cycles of the slit mask (a measurement), each cycle taking a reading for 2*0.14 seconds on each wavelength. Intensity data for six wavelengths, and the dark count, from the five measurements is recorded. The Azimuth and Zenith positions are updated after each measurement.
After each measurement O_3 is calculated, and after the final measurement all data is processed, resulting in a single summary set for the total observation.
An FM measurement takes approximately 15 minutes to complete. Note that FM observations are not valid for ZA>75° and the message ”Waiting for the Moon to Rise above ZA=75” may appear prior to this angle condition being met. See also Appendix A .

FMSUM Focus Moon Data Summary

FMSUM results in the daily Summary (S) file being read and a printout of the ‘summary’ results of the day’s FM measurements being made. An entry is also made to the FMOAVG.nnn file.
The FMSUM command is usually invoked as part of the ED command.

FR Micrometer Reset

FR performs a reset of the wavelength adjust micrometers. The micrometers are moved to reference points, and then moved to the operating points as dictated by offset values contained in the instruments constants file.
The FR command is invoked as part of the RE command, or the operator may manually send the FR command if the positions of the micrometers are suspect.
The FR command may be used to determine new micrometer offset values, but these values should only be changed under the supervision of qualified personnel.
FR results are recorded in the average file, MIOAVG.nnn.
See also Appendix A.

FZ Focused Sun Observation

As the sun drops lower in the sky, the high Mu values result in an increasing amount of scattered radiation in the field of view of a DS observation. The FZ command allows ozone to be determined at solar angles greater than which can be achieved with a traditional DS. Scattered radiation is measured by offsetting the solar image by 1 degree from the entrance slit, and observing radiation in the vicinity of the solar disk. This scattered radiation is then subtracted from the direct sun result to give a more accurate measure of the direct radiation, before the Ozone determination is made. This method will give reasonably accurate O_3 values to ZA of 85° (Air Mass =8.2) as compared to the DS which has cut-off angles of 70 to 80° (Air Mass 3.2 to 5) without corrections. This is a useful command at high latitudes and is normally not used where DS readings are available.
For the FZ measurement the iris is closed, FW#1 is set to position 3, and FW#2 is set to position 5.
The minimum zenith angle at which an FZ may be taken is 73°.
See also DS command.

FZSUM Focused Sun Data Summary

FZSUM command reads the daily Data (B) file and printouts out the ‘summary’ results of the day’s FZ measurements. The FZSUM command is usually invoked as part of the ED command.

GS Gratings Data Collection

GS initiates a routine that collects data required to calculate Grating Slope and Grating Intercept values, which ensure that the two gratings are synchronised during scanning.
The routine performs a scan on slits 1 through 5. Data is written to a GSJJJYY.nnn file, and can be processed by the RD_GS.EXE program to calculate the Grating Slope and Grating Intercept to ensure that the two gratings are synchronised during scanning operations.
GS and RD_GS.EXE are normally run by as part of factory set-up operations or when problems are experienced with the micrometers or gratings.

HG Mercury Wavelength Calibration

HG is used to accurately locate the 302.15 nm line of the Mercury spectrum, and then adjust the diffraction grating such that the five ozone operational wavelengths fall onto the appropriate exit slits.
The zenith prism rotates to the test lamps (position 0), the iris is opened, FW#1 is rotated to the quartz disk (position 1), FW#2 to ND=0 (position 0).
Following the initial set-up and lamp warm-up, the grating is scanned in the forward and reverse direction and the resulting combined spectrum is compared to a stored spectrum. Corrections to the micrometer position are made, and if the adjustment required is greater than 2 steps (.012nm) then the scan is repeated. A test for the presence of Hg lamp radiation is made prior to the beginning of the scan, and if it is not there, an FR test is done to reposition the micrometers to pre-set initialisation values and the test is redone. See also Appendix F and Appendix A.

HGSUM Mercury Lamp Summary

HGSUM reads the daily Data (B) file and prints out the ‘summary’ results of the day’s HG calibrations. In addition an entry is made in the HGOAVG.nnn file.
The HGSUM command is usually invoked as part of the ED command.
See also Appendix A for an explanation of the HGOAVG.nnn file.

HP Grating Synchronisation

It is important that the two micrometers remain synchronised such that they are both set to the same wavelength. The HP test tests for this condition and makes an adjustment, if necessary.
For this test the Standard lamp is used as a light source. The Standard Lamp is turned on, the prism is pointed to lamps, the Iris is opened, FW#1 is set to position 1, and FW#2 is set to position 0. Micrometer #2 is then moved relative to Micrometer #1, and is adjusted such that maximum intensity will occur - an adjustment of more than 10 steps results in the test being repeated.

HV High Voltage Test

The HV command invokes a test used to determine the optimum high voltage setting for the photomultiplier. The HVSET command can then be used to set the High Voltage.
This test is normally used in the factory during the final set-up stages of manufacture, or in the field if it is suspected that the setting is not correct.
The Standard Lamp is turned on, the iris is opened, FW#1 is put to position 1, and FW#2 is set to position 0.
See the HVSET command, and Appendix F for more details on the HV test.

HVSET High Voltage Set-up

The HVSET command can be used to adjust for the optimum High Voltage as determined be the HV test.

IC Instrument Configuration File Update

The IC command results in a display of the Instrument’s current configuration and allows changes to be made by the operator.
See Appendix B for details of the configuration options available.

LF **Location File Update**
The LF command displays a list of some of the known locations of Brewer sites throughout the world. The geographical co-ordinates of the current site may be entered and/or modified.

LL **Location Update**
The LL command allows an operator to change the co-ordinates of a Brewer location, or for the selection of another site contained the location file.

NO **Change Instrument**
The NO command allows the instrument number of the Brewer to be changed. Each Brewer has a set of files which are stored in the C:\BDATA\NNN subdirectory, and which are necessary for proper operation of Brewer NNN. When the NO command is issued, the software is made aware of which Brewer is connected.

NR **No Recording**
This command will turn off recording to the data disk. Data will continue to be printed to the printer, and the 'bytes free' message which normally appears on the screen will be replaced by a "DISK TURNED OFF!" warning message.

See also the DI command.

OZSUM **Ozone Summary**
OZSUM reads the daily Date (B) file and prints out the summary results of the day's O_3 observations. In addition an entry is made in the OZOAVGYY.nnn file.
The OZSUM command is usually invoked as part of the ED command.
See Appendix A for an example of the OZOAVGYY.nnn file.

PB **Data Playback**
Command Syntax: PB BJJJYY.
The PB command allows any previous day's data to be printed using the current temperature coefficients.

PD **Print to Disk**
PD directs printing to a "D" file on the data drive rather than to the line printer.
See also PN, PF.

PF **Printer Off**
PF turns off all printing. Raw data continues to be recorded. See also PN, PD.

PN **Printer ON**
PN directs printing to the line printer. See also PD, PF.

PO **Printout Instrument Constants**
PO generates a printout of the instrument constants file. An example of PO output values can be found in Appendix A

PZ **Point to Zenith**
PZ results in the Zenith Prism being pointed to a Zenith angle of 0° (straight upwards).

QS **Quick Scan**
QS is used in conjunction with the UV Stability Check Kit, and gives an indication of the stability of the instrument in the intensity measurement of UV over the range 290nm to 325nm.

When the equipment has been set up as per the instructions in Section of this manual, and the QS command issued, a report is generated which shows the stability of the instrument at 3.5nm increments using the first generated set of readings as a reference.
For the test, the iris is opened, FW#1 is set to position 3, and FW#2 is set to position 1.
See Appendix A for the LAMP_LLL.nnn file, and Section 6 for more on QS.

QL Lamp Quick Scan
QL is a command based on the QS command. The QL command measures at 12 wavelengths for MKII instruments and at 24 wavelengths for MKIII and MKIV.
Enhancements compared to the QS routine are that QL measures over the complete UV range for all Brewer types, including on slit 5. The QL output file has corrected (not raw) intensities.
For the test, the iris is opened, FW#1 is set to position 3, and FW#2 is set to position 1.
See Appendix A for the QL___LLL.nnn file, and Section 6 for more on QL.

RE Reset
RE initialises all of the Brewer motors (similar to the 'Power On' initialization), and moves them to positions as defined in the Instruments Constants File.
Following a RE, the iris is closed, FW#1 is in position 1 and FW#2 is in position 3.

REP Report
REP displays (or prints) the SLOAVG, HGOAVG, APOAVG, DTOAVG, MIOAVG, and RSOAVG over a user selected range of days.

RS Slit Mask Run/Stop Test
A malfunction in the slit mask motor circuit or in the slit mask itself can result in improper counting and consequently incorrect data. The RS test produces a report on the operation of the Slit Mask Motor by taking measurements in the "Running" and "Stopped" modes of the Slit Mask Motor.
The RS command is normally executed as part of the ED routine and the test results are recorded in the RSOAVG file.
For the RS test, FW#1 is set to position 1, FW#2 is set to position 0 and the iris is open.
RS values consistently outside the range of 0.997 to 1.003 for slitmask positions 2 to 6 should be investigated.
See Appendix F for an explanation of the RS test, and Appendix A for the RSOAVG.nnn file.

SA Solar Angle Printout
SA will generate a printout of GMT vs. air mass, solar zenith angle and lunar zenith angle for the day and location currently in use. Printouts for pasts and future dates are possible by simply changing the Brewer system date.

SC Direct Sun Scan
This test is normally a factory pre-calibration test, the SC determines the optimal operating position of the diffraction grating(s) for taking ozone measurements.
Each individual scan is saved to a SCJJJYY.NNN data file, the SC output average values are added to the SCOAVG.NNN file. This command can be used in schedules.
A set of good sun scans taken between zenith angles of 48 and 66 degrees will provide useful information preliminary to an ozone re-calibration.

SE Schedule Edit
SE is used to create or modify Brewer operating schedules, which are stored as ".SKD" files in the Brewer directory. Brewer schedules consist of two columns of data - a solar zenith angle, and a string of commands. The string of commands is executed at the corresponding solar zenith angle. The SA command is useful for converting GMT to solar angle.
See Section 8 for more on designing schedules.
See also the SK and SKC commands.

SH Slit Mask (shutter) Motor Timing Test

Normally a factory test, the SH command is used to determine the timing constant used in the control of the slit mask motor.
See Appendix F.

SI Solar Siting

Brewer observations using the solar disc as the radiation source require that the Zenith Prism of the instrument be pointed very accurately toward the sun. The SI command is used in the initial set-up of the instrument and for subsequent checking of pointing accuracy. After the date, time, and station co-ordinates have been set accurately, a set of four controls on the front of the instrument are used to introduce 'Horizon' and 'North' corrections which compensate for any offsets that may occur. These corrections are saved and used by the software in future pointing calculations.
See also Section 7.

SIM Lunar Siting

Brewer observations using the lunar disc as the radiation source require that the input window of the instrument be pointed very accurately toward the moon. (Normally the SI command is used if at all possible, as a siting using the moon is much more difficult task than a siting using the sun.) The SIM command is used in the initial set-up of the instrument and for subsequent checking of pointing accuracy in the event that the SI command cannot be used.
After the date, time, and station co-ordinates have been set accurately, a set of four controls on the front of the instrument are used to introduce 'Horizon' and 'North' corrections which compensate for any offsets that may occur. These corrections are saved and used by the software in future pointing calculations.
See also Section 7.

SK Scheduled Operation

SK allows an operating schedule, created by the SE command to be run for the current day. At the end of the schedule, the program returns to the main menu and must be restarted the next day.
See also Section 8, and SE and SKC.

SKC Continuous (scheduled) Operation

SKC allows an operating schedule, created by the SE command, to be run continuously - that is, at the end of the local day a set of summary records is produced (see ED), and the schedule waits for the beginning of the next day and the schedule starts again.
See also Section 8, and the SE and SK commands.

SL Standard Lamp Test

SL initiates the most important quality assurance test in the Brewer commend set. This test essentially performs an ozone measurement using an internal quartz-halogen lamp as the source. The test should be run at least at the start and end of the day and should be preceded by an hp and an hg, The values of R5, R6, and F1 should be monitored carefully, and any changes should be noted and investigated.
For the SL test, the iris is opened, FW#1 is set to position 1, and FW#2 is set to position 0.
See also Appendix F for details on the test.

SLSUM Standard Lamp Summary

SLSUM reads the daily Data (B) file and prints out the 'summary' results of the day's SL tests In addition entries are made in the SLOAVG.nnn file.
The SLSUM command is usually invoked as part of the ED command.
See Appendix A for an example of the SL average files.

SR Azimuth Tracker Steps Per Revolution

SR initiates a test that determines the number of motor steps required for one complete revolution (360°) of the Azimuth Tracker.
The tracker is first zeroed in the counter clockwise direction, and a discrepancy between where the software thought it was, and where the zero reference was found, is output. The Tracker is then moved a full revolution clockwise and the total number of steps required for this movement is output, and the operator is given an opportunity to save the new value. A progressive change of value over time may suggest that Tracker maintenance is required.
See Appendix F.
Tracker maintenance is covered in Section 5.

SS Direct Sun UV Scan

SS results in the Brewer performing a UV scan of the sun through the quartz window. The scan is in 0.5nm steps over the range 290nm to 363nm.
Data is stored in a SSJJJYY.nnn file.
No response file is available for this mode of UV scanning.
See also Appendix A.

ST Status and Control

ST permits the operator to switch the Brewer's internal lamps off and on, and to control all Brewer stepper motors except the Slit Mask Motor.

SUM Summary Data File

SUM reads the daily raw data (BJJJYY.nnn) file and generates a new (SJJJYY.nnn) file which contains only data summary information. In addition, Umkehr data is processed and put into a separate (UJJJYY.nnn) file.
The SUM command, and the various summary printout commands are generally performed at local midnight as part of the ED command.

TE Temperature Printout

TE results in the Brewer temperature (Thermistor #1) in degrees Celsius, along with its equivalent (0 to 5.00v) voltage, to be printed.
If the Brewer has a moisture sensor option, the moisture (in grams/m^3) is also printed or displayed.
See also Appendix A for the average file.

TI Time Set

TI allows the operator to set the internal clock of the Brewer, provided the clock option is turned on in the instrument configuration File. Brewer time is GMT or CUT and is entered as a six digit string (hhmmss). If the internal clock has been turned off in software, there will be an "E" (external) displayed on the computer screen, and the operator will be given the opportunity to turn the internal clock back on. An "I" is displayed on the screen if the system is using the Brewer's internal clock.

TT TeleType Communications

TT sets the Brewer program to its teletype mode, whereby the operator may communicate directly with the Brewer via the computer keyboard and a set of low level commands.
Exit from teletype mode with the home key. Ctrl-x will allow you to retype a line.
See Appendix H for more explanation on the TeleType feature.

TU **Test UV Port Alignment**

TU uses an external quartz-halogen lamp mounted over the UV dome to find the zenith motor step position for which the radiation intensity is a maximum through slit #1 of the spectrometer slit mask.
This is an alignment test and should be performed if alignment of the UV optics is suspect. The results of the factory tests are found in the Final Test Record and are nominally 2112+/- 4 steps.

UM **Umkehr Observations**

UM results in data being collected which can be processed to produce an Ozone vs. Height profile. Data is normally collected between solar zenith angles of 60 ° and 90° in the morning and in the afternoon.
The zenith prism is pointed to a solar zenith angle of 0°, FW#1 is set to the 0 position, FW#2 is set to the 0 position, the iris is opened, and the Tracker is rotated CCW until it is perpendicular to the sun. Intensity measurements are made at two sets of wavelengths - long (320-330nm) and short (310-320nm), and continue until they are interrupted by the operator, or by the next zenith angle in a schedule.
Raw data is put into the BJJJYY.nnn file, and is processed to a UJJJYY.nnn file by the SUM command.
See also Appendix A and Appendix E.

UV **Related Commands**

There are a number of Brewer commands that are related to measurements taken through the Ultra Violet (UV) Dome, and they are grouped together here for convenience. There are typically two UV scan lengths - 'short' UVB scans, which cover the range from 290nm to 325nm, and 'extended' UV scans which cover the range 286.5nm to 363nm.

UA **Timed UX scan**

UA performs an Extended UV scan in 0.5nm increments and stores the data to a UVJJJYY.nnn file. This is a 'timed' routine in that it starts on the next half hour after the command is given.
On execution of the command, the prism is rotated to the UV dome, FW#2 is moved to the 1 position, FW#1 is moved to the 3 position, the iris is opened, and the tracker is pointed at the sun.
See also Appendix A, and the UX command.

UB **UV Summary for Schedules**

Raw UV scan data is stored in a UVJJJYY.nnn data file. The UB scan instructs the program to process and print the daily summary for UV measurements taken throughout the day. Damaging Ultra-Violet values are calculated for each scan and written to a DUVJJJYY.nnn.
See also Appendix A.

UF **Fast UVB scan**

UF results in a UV scan being done in the ascending wavelength direction only.
The zenith prism is rotated to the UV dome, FW#2 is set to the 1 position, FW#1 is set to the 3 position, the iris is opened, and the tracker is pointed to the sun.
The UV spectrum is scanned in steps of 0.5nm, with and integration of 4 shutter cycles for wavelengths less than 300nm, and an integration of 1 shutter cycle for wavelengths grater than 300nm. All data is normalised to a 1 cycle observation and recorded in a UFJJJYY.nnn data file. When scanning is complete, a calculation of the UVB/UVA McKinley - Diffey weighted irradiance is computed and sent to the printer and written to the DUVJJJYY.nnn data file.
See also Appendix A.

UL UV Lamp Scan

UL is a test command that results in a UV scan being performed with a Lamp (rather than the sky) being the source of radiation.
The zenith prism is rotated to the UV dome, FW#2 is set to the 1 position, FW#1 is set to the 3 position, the iris is opened, and the tracker is rotated to the sun. The operator is asked for lamp number, and lamp-diffuser separation, and the radiation intensity is measured in 1.5nm increments over the UVB range.
Data is stored in a ULJJJYY.nnn file.
See also Appendix A.

UV UV(B) Observation

UV results in the irradiance over the “B” region of the spectrum to be measured.
The zenith prism is rotated to the UV dome, FW#2 is set to the 1 position, FW#1 is set to the 3 position, the iris is opened, and the tracker is pointed toward the sun. The UV spectrum is then scanned in steps of 0.5nm from 290nm to 325nm, and then back to 290 nm.
The data is appended to a UVJJJYY.nnn data file.
When scanning is complete, a calculation of the UVB/UVA McKinley- Diffey weighted irradiance is computed, sent to the printer and to the monitor screen, and appended to the DUVJJJYY.nnn data file. A correction is made to the Diffey action spectrum to include the effects of the UVA region 325-400nm).

UVSUM UV Data Summary

This command initiates activity which processes and prints the daily summary of all UV measurements made during that day. DUV values are also calculated for each measurement and data is appended to the UVOAVG.nnn file.
See also Appendix A.

UX Extended UV Wavelength Scan

UX causes the irradiance over the 286.5nm to 363nm range to be measured in 0.5nm increments in ascending wavelength. The zenith prism is rotated to the UV dome, FW#2 is set to the 1 position, FW#1 is set to the 0 position, the iris is opened, and the tracker is pointed toward the sun. The UV spectrum is scanned, and the data is appended to a UVJJJYY.nnn data file When scanning is complete, a calculation of the UVB / UVA McKinley- Diffey weighted irradiance is computed, output to the printer and to the monitor screen, and appended to the DUVJJJYY.nnn data file.
See also Appendix A.

W0-W4 Time delays

These five commands result in time delays of 1, 5, 10, 20, and 30 minutes respectively and can be used in command strings or in schedules.

XL Extended External Lamp Scan

XL is a test command that results in an extended UV scan being performed with a Lamp (rather than the sky) as the source of radiation.
The zenith prism is rotated to the UV dome, FW#2 is set to the 1 position, FW#1 is set to the 3 position, the iris is opened, and the Tracker is rotated to the sun. The operator is asked for lamp number and lamp-diffuser separation, and the radiation intensity is measured in 0.5nm increments over the extended UV range. Data is sampled for 30 cycle time increments through slit #1 for wavelengths less than 300nm and 20 cycle time increments through slit #5 for higher wavelengths.
Data is stored in an XLJJJYY.nnn file and is normalised to 1 cycle observations.
See also Appendix A.

ZB, ZC, ZS Zenith Sky Observations

ZB, ZC, and ZS are variations of the same command, and are used when sky conditions are known and it is desirable to keep the observations separated.
ZB is usually used in clear sky conditions (Zenith Blue), ZC is used under cloudy conditions (Zenith Cloud), and ZS is used when conditions are unknown (as is a schedule).
The zenith prism is pointed to a Zenith Angle of 0°, the iris is opened, FW#1 is set to position 0, FW#2 is set to position 2, and the azimuth tracker is pointed toward the sun. FW#2 is adjusted according to sky intensity.
Data is recorded on disk and is printed as previously determined by PN, PD, and PF commands.
A ZS observation consists of seven sets of 20 cycles of the slit mask (a measurement), each cycle taking a reading for 2*0.14 seconds on each wavelength. Intensity data for six wavelengths, and the dark count, from the seven measurements is recorded. The Azimuth and Zenith positions are updated after each measurement. After each measurement O_3 is calculated, after the seventh measurement all data is processed, resulting in a single summary set for the total observation.
As a safety feature to prevent damage to the detector, the measurement may terminates if, as a result of varying cloud conditions, FW#2 has initially been set to a low attenuation value and clouds suddenly move out of the field of view.
ZP initiates a variation of the ZS command in which the Azimuth Tracker is rotated to an angle perpendicular to the sun.
A ZS measurement takes slightly more than five minutes to complete.
See Appendix A.

ZE Zero Zenith Prism

ZE positions the zenith prism to its zero-step position, or ZA=180°. The zenith reference is found, and the prism is then moved back a constant number of steps from the zero-step position.

5 ROUTINE OPERATIONS AND MINOR MAINTENANCE

This section is written for the Brewer Operator, and is meant to be a guide in determining if the Brewer is functioning correctly. It is assumed that the Operator has attended training by KIPP & ZONEN personnel at the time of installation. No attempt is made to deal with the science of the instrument, as it is assumed that the appropriate Scientists are interrogating the data and that they have reasonable knowledgeable of both the Brewer instrument and Atmospheric Science.
A properly functioning Brewer requires a relatively small amount of work, but periodic checks and minor maintenance must be done regularly to ensure that high quality data is being recorded. In this manual the terms Daily, Weekly, and Infrequent are used for frequency of tasks, but local conditions may dictate different intervals.

5.1 DAILY TASKS

Daily tasks are divided into 'Outside Tasks', and 'Inside Tasks' –i.e. those performed at the Brewer, and those performed at the Computer. These instructions are written assuming that the Brewer is running in a 'Scheduled' operation.

Outside Tasks

1. Check that the Tracker is pointing toward the Sun, toward the Moon, or perpendicular to the sun, depending on the measurement in progress.
2. Check that the Tracker Power Lamp is illuminated, and that the Tracker cables are not tangled or pulled tight.
3. Check that the Brewer Power lamp is on.
4. Use a soft cloth and mild glass cleaner to clean the UV Dome and the Front Window.
5. If the Brewer has a humidity indicator under the viewing window, check its status.
6. If any of the above are abnormal, then make corrections, and make a note in the "Brewer Log Book"

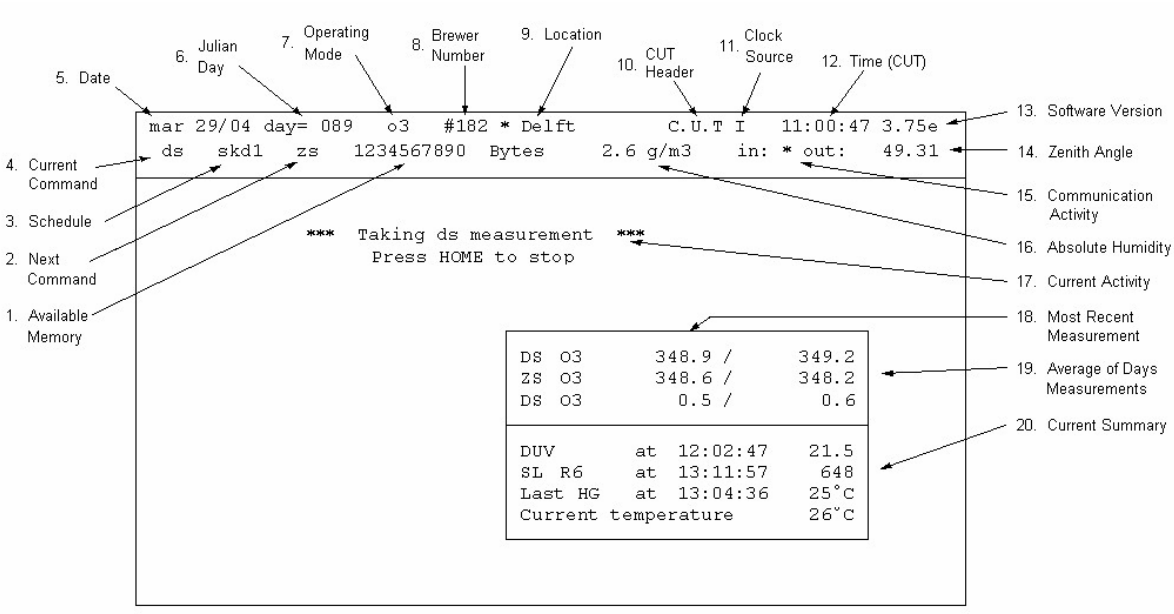
Inside Checks

Interrogate the Computer Screen and confirm that it is normal.

#	Name	Example	Description
1.	**Available Memory**	**1234567890**	-the amount of free space on the Brewer Data drive
2	**Next Command**	**Zs**	- indicates the next command to be executed
3.	**Schedule**	**Skd1**	- Indicates the current Schedule being executed
4.	**Current Command**	**Ds**	-Indicates the current Routine being executed -'menu' is displayed if a schedule is not running
5.	**Date**	**Jan 15/99**	- the GMT date which will change at 00:00:00 GMT - adjust using the DA command
6.	**Julian Day**	**015**	- changes at solar midnight - adjust using the DA command
7.	**Operating Mode**	**O_3**	- indicates that the Brewer is in Ozone mode - no adjustment
8.	**Brewer Number**	**159**	- specifies constants for the Brewer - adjust using the NO command
9.	**Location**	**Saskatoon**	- determines Site specific information - change location with LL command - change Site information with LF command
10.	**Moisture Index**	**2**	- used to indicate if the desiccant needs changing. - change the desiccant if index values are consistently greater then 10.
11.	**CUT Header**	**C.U.T**	- reminder that time is Co-ordinated Universal Time (Greenwich Mean Time)
12.	**Clock Source**	**I or E**	- indicates if the System is using the Brewer Clock (I) or the Computer clock (E). - Brewer clock can be toggled ON or OFF in the Configuration File with the IC command
13.	**Time (CUT)**	**15:32:19**	- indicates the system time, and should be within 20 seconds of GMT for proper tracking. - adjusted with TI
14.	**Software Version**	**374f**	- the Version number of the Brewer Software
15.	**Zenith Angle**	**45.76**	-the current Solar Zenith Angle
16.	**Communication Activity**	**in: out:**	- these fields were originally intended to monitor communications between the Computer and the Brewer -As Computer speed increases, the usefulness of these indicators decreases -The Data Set is a much better indicator of Communications.
17.	**Absolute Humidity**	**0.0 g/m3**	- if the Brewer is fitted with a moisture sensor option, this field indicates the amount of moisture in one unit volume of air in the Brewer enclosure.

18.	**Current Activity**		- Comments about what the Brewer is currently doing.
19.	**Most Recent Measurement**	**429.4**	- Most recent successful measurements of a certain type (ds O3, zs O3 and ds SO2).
20.	**Ave. of Day's Measurements**	**430.7**	- Average of all successful measurements of a certain type taken in the current day.

A typical screen is shown below.


5. Date
6. Julian Day
7. Operating Mode
8. Brewer Number
9. Location
10. CUT Header
11. Clock Source
12. Time (CUT)
mar 29/04 day= 089 o3 #182 * Delft C.U.T I 11:00:47 3.75e
ds skd1 zs 1234567890 Bytes 2.6 g/m3 in: * out: 49.31
4. Current Command
3. Schedule
2. Next Command
1. Available Memory
*** Taking ds measurement ***
Press HOME to stop
DS O3 348.9 / 349.2
ZS O3 348.6 / 348.2
DS O3 0.5 / 0.6
DUV at 12:02:47 21.5
SL R6 at 13:11:57 648
Last HG at 13:04:36 25°C
Current temperature 26°C
13. Software Version
14. Zenith Angle
15. Communication Activity
16. Absolute Humidity
17. Current Activity
18. Most Recent Measurement
19. Average of Days Measurements
20. Current Summary

The lower part of the screen indicates in real time what tasks the Brewer is performing, and there is a Status Box which shows some important status information including:

- the latest DUV measurement
- the running average O_3 values
- the latest SL " R6 " value
- the latest HG measurement time and temperature
- the current temperature

If the software has crashed, then an error and a program line number will be displayed on the screen.
A glance at the screen will determine if the Brewer is operating as expected, and any discrepancies should be noted and corrected.

END OF DAY PRINTOUT

Look at the End of Day printout (or "D" file if PD is used in ED) and check especially the diagnostic tests, and summary data.

1. **HG SUMMARY**
   There should be no errors printed which might indicate a Micrometer positioning problems.
   Check that there are no (or few) cases where it appears that the HG required multiple attempts do complete a successful calibration.
   Note the Intensity and watch for trends in intensity increasing or decreasing.

2. **SL SUMMARY**
   Note the R5 and R6 ratios and the F1 intensity, and watch especially for sudden changes that could indicate a malfunction.
   Gradual changes over time are to be expected.
   Make a plot (or plot the SLOAVG) file every week or two to look for deviations from the norm of the three parameters.
   Changes in R5 and R6 are associated with changes in the Brewer performance which could be reflected in errors in the O_3 and SO_2.

3. **RS TEST:**
   RUN / STOP ratios for wavelength 0 and 2-6 should be 1.000 +/- 0.003
   If larger deviations are found, then confirm them to be repeatable before taking any corrective action.

4. **DT TEST:**
   The two summary values should be within a few (5) nanoseconds of the values given in the Final Test Record.
   If larger deviations are found, then confirm them to be repeatable before attempting any corrective action.

5. **HP TEST:**
   The test should be successful in one or two attempts.
   If multiple attempts are required on a regular basis, corrective action may be necessary.

6. **RESET**
   The Reset portion of the printout gives values of Azimuth, Zenith and Micrometers zeroing discrepancies.
   Inspect these discrepancies and confirm that they are repeatable prior to attempting any corrective action.

7. **AP PRINTOUT:**
   Inspect the monitor values and look for consistent deviations and trends from the Final Test Record, or from previous values.

8. **RL PRINTOUT**
   The Log file printout should be inspected for any errors that the firmware detected, or thought it detected.
   If the errors persist then KIPP & ZONEN should be consulted for advice.

9. **OBSERVATION DATA:**
   Data file summaries should be inspected to ensure that they are present, and data should be reviewed as per instructions from the Scientific Authority for the Brewer station.

5.2 WEEKLY TASKS

There are a number of tasks which should be performed and results recorded at least weekly.

1. Steps per Revolution (Section 6.14)
2. Solar Siting (Section 7)

5.3 INFREQUENT TASKS

This section deals with true 'infrequent' tasks, as well as those that are more for the integrity of the data than for the operation of the Brewer. The timing of many of these tasks is usually determined by the "Scientific Authority" of the observation site.

1. UV Stability Check (Section 6)
2. Mechanical Checks
3. UV Calibration
4. Ozone Calibration

5.4 MINOR MAINTENANCE

Routine maintenance deals with periodic checks and adjustments that the Operator should do to ensure correct operation of the Brewer. These items are not failures, but may lead to failures, or result in poor data if not attended to.

Desiccant Changes
Moisture is one of the worst enemies of the Brewer and can cause damage to the Optics which often can be corrected only by returning the Brewer to the factory for parts replacement and recalibration.

There are two desiccant systems in the Brewer - the desiccant cartridge 'breather' and the loose, or bagged desiccant.

The desiccant cartrige is intended to remove moisture from the air drawn into the Brewer as temperature changes. This container can be inspected from the underside of the Brewer base by removing two 'thumbscrews. If the desiccant is no longer Blue, then it requires changing.

Loose or bagged desiccant is intended to remove moisture from inside the Brewer enclosure.
If the Brewer is equipped with a Moisture Sensor, then the Moisture Index is displayed on the Computer Display. The maximum safe level for the Moisture Index is 10.

If the Brewer is not equipped with a Moisture Sensor, then Humidity Sensors placed beneath the Brewer Viewing Window should be inspected regularly. If the 40% indicator starts to turn Pink, the moisture is approaching the danger level.

If either of the two potentially dangerous conditions of moisture is viewed, then the desiccant in the Brewer enclosure should be changed.
The desiccant container mounted in the rear of the Spectrometer should be inspected each time the Brewer cover is removed, and the desiccant replaced whenever it is observed that the indicator is in the 40% region.

Tracker Drive Mechanism - See Figure 5.2
If the Steps per Revolution test returns an erratic result, or a variance that is more than about 20 steps, then the large aluminum drive wheel and the small stainless steel drive rod should be inspected and cleaned with a dry tissue.

If no slippage is observed in the SR, then the cleaning should be done approximately every 3 months.

If Tracker slippage is not due to dirty drive gears, then drive gear tensions should be checked.

The friction drive arm is set with 9 kg of tension on the lower spring and 4 kg on the upper spring to provide drive friction and gear mesh pressures respectively.

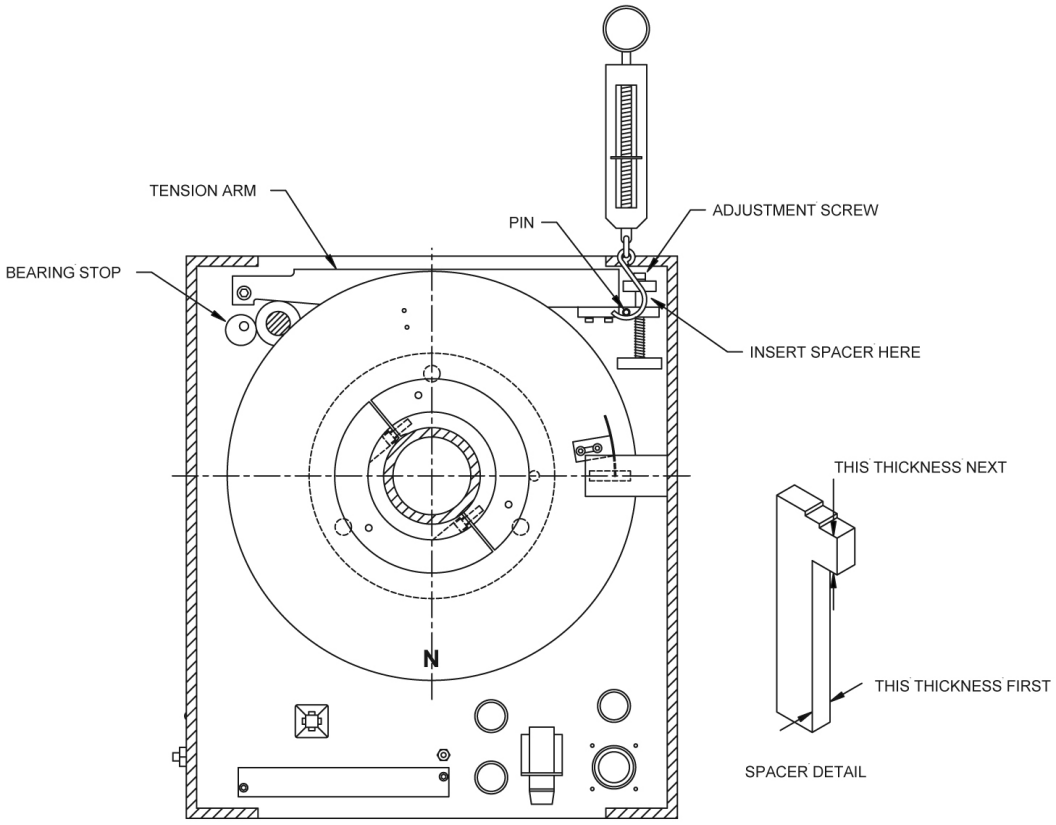


Figure 5.2. Tracker Drive Mechanism

Zenith Drive
The middle gear on the zenith drive has a hole to allow a small drop of low temperature rated light oil to be applied approximately once a year.

The Zenith drive gears can be cleaned with a lint-free cloth at the same time.

Cover Latches
In very moist climates, the internal mechanism of the cover latches can become rusted and become very difficult to turn.

Applying a few drops of light oil periodically will help to prevent this annoyance.

Levelling Feet
In very moist climates the adjusting mechanism on the Tripod legs can become rusted, making them impossible to turn.

Applying some grease to the exposed parts periodically will help to prevent this problem.

Micrometers
There may be occasions when one or both micrometers will have to be reset by hand, and the normal settings are recorded on the Spectrometer Cover.

This problem may occur if the constants for Micrometer Offsets, or the Micrometer Steps /Degree are not correct, or if the mechanism becomes sticky.

The constants should normally not be changed without further investigation, but the mechanism may be cleaned with a lint-free cloth.

The micrometers should normally not require lubrication, and the only lubricant KIPP & ZONEN uses in the Spectrometer is High Temperature Miller Stephenson KRYTOX GPL 200 Grease.

Standard Lamp and Mercury Lamp
The two internal test lamps (Standard Lamp and Mercury Lamp) have an estimated lifetime of about two years.

The Standard Lamp can be accessed by removing the plate located behind the Zenith Drive Motor.

Once the two screws are removed, the plate can be detached, bringing with it the lamp socket and the lamp.

Great care must be taken not to touch the new lamp with bare hands as oil and/or moisture may change the spectral characteristics of the lamp.

The Mercury Lamp may be changed by loosening the two thumbscrews on the lower part of the Lamp Assembly.

The Lamp and its socket can then be slid forward (toward the PMT), and the new lamp installed.

Great care must be taken not to touch the new lamp.

When replacing the lamp and socket, observe that there is a small aligning pin at the top of the assembly. The mercury filament is to be installed in vertical position.

Backup Battery
The Clock battery on the Main Electronics PCB has an extremely long lifetime under normal operation (power always on) of the Brewer, and it is unlikely that it will have to be changed for many years.

In the event that the Battery does require replacement, it can be accessed on the PCB by removing the seven screws securing the rear PCB protective plate, and sliding the plate up.

The battery is located on the lower left hand corner of the main circuit board.
Prior to removing the battery the power should be turned off, and the small jumper immediately to the right of the battery should be removed.

The battery can then be slid to the left and taken from its holder and replaced with a 3v Lithium Battery, KIPP & ZONEN partno. 75-01-020.

Following replacement, the jumper must be replaced, the panel put back on, and the Brewer given a cold start.

6 UV STABILITY CHECK - QL

Objective:
To verify the instrument stability for UV measurements with the optional BA-C126 UV Stability Kit. The stability kit contains five 50W quartz envelope UV lamps.

Recommended Frequency of Check:
Approximately once every two weeks.

Limitation:
The UV calibration check procedure assumes KIPP & ZONEN 'S portable UV lamp assembly, BA-C126, is to be used. This assembly is intended for monitoring instrument stability and NOT to give an absolute responsivity calibration. It is recommended that a NIST traceable 1000W lamp operated at 50 cm distance from the Teflon diffuser be used for absolute calibration.

Lamp Set-up:

1. Ensure the UV Dome is clean. This may be achieved by using a lint free soft cloth or tissue (Kim Wipes), and clean water, or a mild cleaner.(Windex, isopropyl alcohol, distilled water).
2. When facing the front of the Brewer, position the Lamp Housing on top of the UV quartz dome with the nylon legs snug up against the left edge of the Brewer cover. Slide the lamp housing left and the nylon legs right and tighten the legs to ensure lateral repeatability.
3. Select the lamp to be tested. Note the three digit serial number. Vertical repeatability is achieved by positioning the lamp filament on exactly the same axis as that defined by the two sight holes on each side of the lamp shield. This axis represents 5cm from the Teflon diffuser. Verify that the hole in the filament coil is centered by looking through the two holes in the lamp assembly. If the coil is visible between the two holes, it needs to be adjusted. The lamp centering can be adjusted if necessary by pushing it slightly to one side or the other.

   DO NOT touch the lamps with your fingers or allow them to come into contact with any wet or dirty materials. This will reduce the life of the lamp.
4. Remove the rectangular lamp cover located on top of the lamp housing by unscrewing the nylon thumbscrew. Insert the lamp into the 6 pin socket, ensuring that it is seated completely into the socket. The aluminium shield around the lamp is keyed with the housing to keep the lamp right side up.
5. Place the UV test case on top of the Brewer. Connect the meter. Connect and latch the lamp supply cable, and plug the AC cord into the power outlet under the Tracker. Turn the lamp power supply on.

   CAUTION! These lamps emit UV radiation which can be harmful to your eyes. Always ensure the lamp cover is in place **before** turning the power on.

6. Press the yellow button of the Voltmeter while turning the meter from the OFF position to the DC VOLTS position. Release the button after two or three seconds. The meter will display three decimal places. (If the yellow button is not depressed while turning on the Voltmeter, it displays two decimal places.)
7. Allow the lamp to warm up for about 10 minutes. Periodically adjust the voltage to maintain a stable level of 12.000 +/- 0.003 volts.

   NOTE: The external tungsten-halogen lamp should be operated at a constant ambient temperature. For this reason, it is recommended to perform the stability check on a dry day when the winds are calm.

Computer Set-up:

1. Press **Home** to interrupt the Brewer schedule and return control to the Main Menu screen.
2. Issue the **hphg** commands. The HP will execute, and after a 5 minute lamp warm-up, the HG will perform a wavelength calibration.
3. Type the command sequence **pdqlhphg** and press **Enter**.
   - **pd** turns on the printer
   - **ql** initiates a "Quick Lamp Scan" of the UV lamp
   - **hp** aligns the gratings
   - **hg** does a mercury line wavelength calibration
4. When prompted to do so, enter the following:
   - the 3 digit lamp number.
   - press **Return** when prompted to confirm detector distance is 5 cm.
   - if the voltmeter is stable at 12.000 volts, press **delete** to bypass lamp warm-up delay.
5. The software will then initiate the four commands in sequence and print the results on the screen and o the D-file. Note the **pf** command must be used to close this file properly.

   The "quick lamp scan" print-out lists the following:
   - measurement wavelength, in nm.
   - lamp intensity in counts per second
   - percent change from initial measurement in the QL_lamp.### file

Subsequent Lamps:

1. After the "quick scan" has finished, the UV lamp power supply can be turned off and the **VERY HOT** lamp can be removed from the socket. The lamp should be allowed to cool adequately prior to storing back in the case.
2. Repeat the test for each lamp to be scanned.

   CAUTION! These lamps have a limited life expectancy. Do not leave the lamps on for an extended period.

General Instructions:

1. Three lamps should be scanned bi-weekly. If all three lamps give approximately the same results, then the test is complete. If one lamp gives results that are different from the other two, then a fourth lamp should be chosen and the scan run yet another time. The lamp giving the 'odd' reading should be noted and not used again.

2. Once every two months, all five lamps should be scanned to make sure they all give the same results so availability of spares is assured.

3. In the event that the % difference for all lamps is much greater than 5%, it may be necessary to perform other scans which will be used to create new response files for the instrument. See Appendix C.

4. Perform the TU test prior to changing the response file to make sure that the Zenith Prism is properly aligned. See section 4.

7 SOLAR AND LUNAR SITING - SI, SIM

Accurate measurements depend on the instrument being aligned very accurately to the Sun (or Moon). Not only is this important for the direct measurements, but for reasons of polarisation and consistency, it applies to all measurements.

During installation, care is taken to ensure that the Brewer is oriented properly, but it is not possible to mechanically align the Tripod and the Tracker to the accuracy required.

Following installation, the SI (SIM) command can be used to determine both “NORTH CORRECTION” and “HORIZON CORRECTION” information which are used to compensate for any solar misalignment of the instrument.

It is assumed that the date is correct, that the time is accurate to within 20 seconds of GMT, and that the co-ordinates of the site are accurate to two decimal places of latitude and longitude degrees.

The following procedure applies to both SI and SIM commands.

SI Procedure

1. From the Main Menu, issue the command sequence PDSRSI.

- PD turns on the printer
- SR zeros and resets the Tracker
- SI puts the software into the Siting Mode
- the default mode enables the controls on the Brewer

2. Being careful not to block the sun, look into the “Entrance Slit View Tube”.

If a bright diffused image is nowhere to be seen, then go to step 4.

3. Using the UP/DOWN and CW/CCW controls on the front of the Brewer to move the Zenith Prism and/or the Azimuth Tracker such that the diffused image is dissected by the black rectangular image of the entrance slit.

Go to step 5.

4. Being careful not to block the Sun, look into the “Iris Viewing Tube”.

If the Azimuth pointing is accurate to within about 10°, then a bright image of the Sun will be seen.

If no image is seen, and none was seen in step 2, then the Tracker will have to be put into rough alignment by observing shadows cast by various parts on the Brewer, and pushing the CW or CCW buttons until an image appears.

Once the image is seen in the Viewport, the UP/DOWN and CW/CCW controls are used to move the image into the aperture of the iris.

When the image disappears into the Iris aperture, then go to step 2.

5. Return to the Computer and follow the instructions for saving the new siting information.

   Before saving new values, recheck that the Date and Time are correct.
   For accurate tracking to take place the Tracker must be quite level.
   Levelling can be checked by alternating the times of day when siting is done - check the siting in the early morning on one day, and in the late afternoon on another.
   If it is found that the North Correction numbers alternate between higher and lower numbers consistently from morning to afternoon then this is an indication that the levelling is not accurate.
   If there are very inconsistent North Correction values from one siting to another, this could be an indication of the Tracker drive mechanism slipping.
   If there are inconsistent Horizon Correction values, this could be an indication of Zenith Prism slippage.
   If there is a constant drift in both Horizon and North corrections, then this could be an indication that the site co-ordinates could be incorrect.

8 BREWER SCHEDULES - SE, SKC, SK

A most important feature of the Brewer is its capability to run for longs periods of time in an unattended state.
The Brewer system is able to achieve this Automatic operation the use of Schedules Operation.
A schedule is simply a file containing a list of instructions which the Brewer software executes.
A series of commands is triggered by the Sun reaching a Solar Zenith Angle (SZA) as prescribed by the Scientific Authority for the observation site.

Scheduling Hints and Conventions:

- Schedules are created or altered using the SE command.
- While in SE, the ^ (shift 6) keys may be used to turn on a flag which causes the Ins and Del keys to insert or delete full lines.
- The SA command is a convenient tool for relating the time (GMT) to the SZA.
- In schedule convention, SZA before noon are considered to be -ve, and after noon they are +ve.
- Schedule names follow DOS rules, and automatically are given the SKD extension.
- An ED is invoked automatically at solar midnight by the SKC routine so an additional ED need not be programmed into the schedule.
- Schedules may be “linked”
- when running a schedule under SKC, the schedule automatically starts the next day.
- when running a schedule under SK, the schedule does not automatically start the next day.
- all entries in a schedule are keyed to the SZA, even if they are ‘moon’ measurements.
- only two character commands can be used in a schedule
- an integer can be entered at the end of a command line to indicate how many times the command line is to be repeated i.e. DSZSDS3 will cause the commands DSZSDS to be repeated three times.
- the next SZA will interrupt the current command line when the command in process is finished.
- the HPHG sequence is normally inserted such that the internal temperature of the Brewer does not change more that 2°C between HG’s.

HG commands should also be done more frequently in sections of the schedule that have much micrometer movement i.e. UV and UM.

Approximate run times for the following measurements are shown below:

HG (without	7-9 min.
SL(without B2)	9 min
DS	3 min
ZS	4 min
UV	8 min
UX	6 min
UM	Indeterminate must be aborted with HOME key or new schedule entry
FM	11 min

Writing Schedules:

- Determine the Scientific Objectives, and draw up a table of Solar Zenith Angle vs. Commands.
- Use the SA command to assist in relating to local time.
- From the Brewer main menu, send the Command SE.
- a table will appear on the screen with two columns, one for SZA, and one for the commands to be executed at the SZA.
- starting with the first SZA after solar midnight (it will probably be -ve), enter the SZA in the left hand column of the table, and enter the commands to be executed at that angle in the right hand column.
- carry on through the day, remembering that the SZA changes to +VE after noon (no sign defaults to +ve).
- when the schedule is finished, press Ctrl+End and follow the instructions for saving the schedule.
- the schedule can be tested using the SK or SKC routines.

APPENDIX A BREWER DATA FILES

D Files: DJJJYY.nnn -- 'D' or Disk files are produced when the PD command has been issued, causing the software to 'print to disk'.
These files usually contain end-of-day summaries and/or test data.

B Files: BJJJYY.nnn 'B', or Brewer, files contain the raw data collected by the Brewer.
B files begin with the characters "version". The beginning of a B file contains three sections: the version string, the instrument constants, and a data header.
Following is a description of the format of each B file section.

Data Header
Each B file begins with a data header.

Example	Name
Version=2	B file version number
Dh	Header
25	Day
11	Month
98	Year
Saskatoon	location name
52.108	latitude
106.713	Longitude
3.45	temperature in volts
Pr	Pressure header
1000	Mean Pressure

Temperature, in volts (TE%) - Read from the PMT thermistor. The temperature in °C is calculated using the equation: $Temp(C) = -33.27 + TE\% \times 18.64$

Instrument Constants
This section of the B file starts with the header "inst". See Appendix B for the format of ICFJJJYY.nnn.

Dispersion constants
This section of the B file starts with the header "disp". See Appendix B for the format of DCFJJJYY.nnn.

Zenith Sky Constants
This section of the B file starts with the header "zeni". See Appendix B for the format of ZSFJJJYY.nnn.

Comment Block
Comments may be generated by the user with the CO command, and may also be automatically generated by some routines.

Example	Name
Co	Comment header
13:20:14	Time comment was logged
User: text	Comment source: comment text

HG Calibration Data

Example	Name
Hg	Type of measurement
12:10:22	Time of measurement
.9995	Correlation value
287.1829	Calculated micrometer step
287	Micrometer set to this step #
190255	Peak intensity of the HG scan
28	Temperature (deg. C)

Correlation Value: - The corelation between the stored and measured spectra.
- Calculated Micrometer Step number
- The micrometer position of the HG peak

Standard Lamp Test Data

#	Example	Name
1	Sl	type of measurement
2	A	Filter
3	0	ND filter position of filterwheel #2 (in steps)
4	737.41	time – minutes since 00:00 hrs
5	0	Lower slit mask position (1=dark)
6	6	Upper slit mask position (6=slit 5)
7	20	# of cycles
8	625382	raw counts wavelength #0
9	43	dark count
10	644575	raw counts wavelength #1
11	710539	raw counts wavelength #2
12	839228	raw counts wavelength #3
13	914419	raw counts wavelength #4
14	981043	raw counts wavelength #5
15	Rat	ratios header
16	1543	single ratio #1 MS(4)
17	1116	single ratio #2 MS(5)
18	385	single ratio #3 MS(6)
19	300	single ratio #4 MS(7)

These lines are repeated for a total of 7 sets of data per SL test. This data is then averaged in the following summary.

#	Example	Name
1	Summary	Summary header
2	12:19:09	Time
3	mar	Month
4	08/	Day
5	98	Year
6	104.612	mean zenith angle during measurement
7	3.777	mean airmass
8	6	temperature (deg. C)
9	sl	type of measurement
10	0	ND filter position (in steps)
11	1523	mean single ratio #1 R1 MS(4)
12	662	mean single ratio #2 R2 MS(5)
13	-126	mean single ratio #3 R3 MS(6)
14	-783	mean single ratio #4 R4 MS(7)
15	4028	mean double ratio #1 R5 MS(8)
16	2056	mean double ratio #2 R6 MS(9)
17	824997.5	mean of counts from wavelength #1
18	971515.6	mean of counts from wavelength #5
19	2	standard deviation of single ratio #1
20	3	standard deviation of single ratio #2
21	4	standard deviation of single ratio #3
22	4	standard deviation of single ratio #4
23	13	standard deviation of double ratio #1
24	8	standard deviation of double ratio #2
25	387	standard deviation of counts wavelength #1
26	632	standard deviation of counts wavelength #5

Direct Sun Data

#	Example	Name
1	ds	type of measurement
2	a	Filter
3	64	ND filter position of #2 Filterwheel (in steps)
4	978.87	time - minutes since 00:00 hrs
5	0	lower slit mask position (1=dark)
6	6	upper slit mask position (6=slit 5)
7	20	# of cycles
8	625382	raw counts wavelength #0
9	11	dark count
10	13879	raw counts wavelength #1
11	345676	raw counts wavelength #2
12	437926	raw counts wavelength #3
13	728264	raw counts wavelength #4
14	805262	raw counts wavelength #5
15	rat	ratio header
16	15671	single ratio #1 MS(4)
17	8345	single ratio #2 MS(5)
18	2820	single ratio #3 MS(6)
19	1	single ratio #4 MS(7)

These lines are repeated for 5 DS measurements which are then averaged.

#	Example	Name
1	Summary	Summary header
2	16:20:02	Time
3	mar	Month
4	08/	Day
5	92	Year
6	68.024	zenith angle
7	2.617	Airmass
8	-5	Temperature (deg. C)
9	ds	type of measurement
10	1	ND filter pos'n
11	15578	single ratio #1 MS(4)
12	8312	single ratio #2 MS(5)
13	2801	single ratio #3 MS(6)
14	-5	single ratio #4 MS(7)
15	15594	double ratio #1 MS(8)
16	6920	double ratio #2 MS(9)
17	.3	SO_2value MS(10)
18	404.4	O_3 value MS(11)
19	71	st'd dev. Single ratio #1
20	28	st'd dev. Single ratio #2
21	16	st'd dev. Single ratio #3
22	5	st'd dev. Single ratio #4
23	56	st'd dev. Double ratio #1
24	11	st'd dev. Double ratio #2
25	.4	SO_2 st'd dev.
26	.6	O_3 st'd dev.

Zenith Sky Data

#	Example	Name
1	zs	type of measurement
2	a	Filter
3	0	ND filter pos'n in filter wheel motor steps
4	974.43	time – minutes since 00:00 hrs
5	0	lower slit mask position
6	6	Upper slit mask position
7	20	# of cycles
8	625382	raw counts wavelength #0
9	4	dark count
10	10125	raw counts wavelength #1
11	48805	raw counts wavelength #2
12	164527	raw counts wavelength #3
13	306533	raw counts wavelength #4
14	311495	raw counts wavelength #5
15	Rat	ratio header
16	14857	Single ratio #1 MS(4)
17	8021	single ratio #2 MS(5)
18	2727	single ratio #3 MS(6)
19	79	single ratio #4 MS(7)

These lines are repeated for a total of 7 measurements, which are averaged.

#	Example	Name
1	Summary	Summary Header
2	16:16:09	Time
3	Mar	Month
4	08/	Day
5	92	Year
6	68.477	zenith angle
7	2.667	air mass
8	-5	Temperature (deg. C)
9	zs	type of measurement
10	0	ND filter position
11	14757	single ratio #1 MS(4)
12	8003	single ratio #2 MS(5)
13	2704	single ratio #3 MS(6)
14	72	single ratio #4 MS(7)
15	14526	double ratio #1 MS(8)
16	6528	double ratio #2 MS(9)
17	-48.6	SO_2 value MS(10)
18	404.8	O_3 value MS(11)
19	57	st'd dev. Single ratio #1
20	29	st'd dev. Single ratio #2
21	13	st'd dev. Single ratio #3
22	5	st'd dev. Single ratio #4
23	51	st'd dev. Double ratio #1
24	21	st'd dev. double ratio #2
25	3.2	SO_2 st'd dev.
26	2.1	O_3 st'd dev.

Umkehr Data

Umkehr data taken alternately at 5 ‘short’ wavelengths and 5 ‘long’ wavelengths. The short/long wavelength measurement sequence is repeated for as long as the UM command is engaged. The following data is from a measurement at short wavelengths.

#	Example	Name
1	Um	type of measurement
2	25	Day
3	11	Month
4	98	Year
5	Saskatoon	location name
6	52.1	Latitude
7	106.7	Longitude
8	3.49	last temperature (volts)
9	pr	Pressure header
10	1000	Mean pressure (milli bars)
11	0	ND filter position
12	1157.87	time - minutes since 00:00 hrs.
13	1	lower slit mask position
14	6	upper slit mask
15	40	# of slitmask cycles

16	625382	raw counts wavelength #0
17	120	dark count
18	97706	raw counts wavelength #1
19	294523	raw counts wavelength #2
20	759956	raw counts wavelength #3
21	1087648	raw counts wavelength #4
22	962462	raw counts wavelength #5
23	rat	Ratio
24	105525	Single ratio #1 MS(4)
25	5722	Single ratio #2 MS(5)
26	1572	Single ratio #3 MS(6)
27	-574	Single ratio #4 MS(7)

S Files: SJJJYY.nnn - 'S', or Summary files contain summary information from each test and measurement contained within the B file for the same day
The data contained in the S file is essentially the same as the "summary" line of the B file. SJJJYY.nnn files start with a "tc" and the 5 temperature coefficients which were in the instruments constants file when the SUM command was issued. The SUM command is normally performed as the first command in the ED end of day sequence. Each item in a S-file is separated with a carriage return and line feed, the end of the summary file is marked with "ef".

UV Files UVJJJYY.nnn - 'UV' files contain data data from UV scans, Including UV, UX, and UA

#	Example	Name
1	UX integration time is 0.2294 seconds per cycle	(header for each scan).
2	dt 4.3E-08	Dead time
3	cy 1	# of cycles
4	Dh	Data header
5	26	Day
6	04	Month
7	92	Year
8	Saskatoon	Location
9	52.108	Latitude
10	106.713	Longitude
11	2.56	Temperature (volts)
12	Pr	Pressure header
12	960 dark	Pressure (mb) and dark count header
14	1	Dark count
15	825.9	Time (GMT) in minutes for 1st λ
16	2865	Wavelength for 1st λ
17	1263	Micrometer step # for 1st λ
18	11	raw counts for 1st λ
19		Lines 15 to 18 are repeated for each λ

In UX scans, lines 15 to 18 are repeated for wavelengths 286.5nm to 363.0nm in 0.5nm increments. In UV measurements the scan is from 290.0nm to 325.0nm then back to 290.0nm in 0.5nm increments and the number of cycles is 4 and counts for 4 cycles are recorded in the UV file.

Umkehr Files: UJJJYY.nnn -- As part of the End-of-Day process the Umkehr data in the B file is transferred into a U file which contains both morning and evening data if it has been collected.

XLJJJYY.nnn - Extended Lamp Scan

#	Example	Name
1	Integration time is 0.2294 seconds per cycle	Integration time
2	dt 3.4E-08	dead time
3	cy 1	number of slit mask cycles
4	le 154	Increments in the 290-325 nm region
5	ln 608	lamp serial number
6	di 5	distance between filament and teflon diffuser
7	dh	data header
8	15	Day
9	01	Month
10	99	Year
11	Saskatoon	Location
12	52.108	Latitude
13	106.713	Longitude
14	3.43	PMT temperature (Volts)
15	pr	Pressure header
16	960 Dark	Pressure (milli bars) and Dark Count Header
17	1	dark count
18	960.8	decimal minutes since 00:00 hours
19	2865	Wavelength (Angstrom)
20	256	micrometer step number
21	121.1	raw counts
22		lines 18-21 repeat for wavelengths from 2865A to 3630A in 5A increments
...		
633	end	end of measurement

A/D Values: -- A/D values are not stored in files (except HV and +5v and SL current), but they are very important in assessing the health of the Brewer, so they are included here for reference.

A/D Values for nov 15/98 at 17:03:05 for instrument number 159

Channel#	Name	Value (Lamps off)	Value (Lamps on)
0	PMT temp (deg C)	28.50	28.50
1	Fan temp (deg C)	27.83	27.83
2	Base temp (deg C)	28.21	28.21
3	H.T. voltage (V)	1487.05	1487.05
4	+12V power supply (V)	11.91	11.91
5	+ 5V power supply (V)	4.97	4.97
6	-12V power supply (V)	-11.99	-11.99
7	+24V power supply (V)	24.48	24.48
8	Rate meter (V)	0.00	0.00
9	Below Spectro temp (C)	27.07	27.07
10	Window area temp (C)	28.50	28.50
11	External temp (deg C)	27.55	27.55
12	+ 5V ss (V)	5.00	5.00
13	- 5V ss (V)	-4.91	-4.91
14	Std lamp current (A)	0.00	1.57
15	Std lamp voltage (V)	0.00	10.00
16	Mer lamp current (A)	0.00	0.36
17	Mer lamp voltage (V)	0.00	11.46
18	External 1 (V)	0.07	1.36
19	External 2 (V)	0.05	0.70
20	External 3 (V)	1.19	1.19
21	Humidity (g/m3)	3.74	3.74
22	External 4 (V)	0.02	0.12
23	External 5 (V)	0.03	0.13

PO Values: -- The PO command generates the following.

```
                              MKIII BREWER INSTRUMENT #159
                              ----------------------------
                               01-05-1998  17:02:42

*************************************************************************
* Ozone Values   *    1    *    2    *    3    *    4    *    5    * hg   *
*************************************************************************
  Wavelength(nm) * 306.289   310.035   313.486   316.787   319.978  303.184
  Temp. Coeff    *  0.0000   -0.2473   -0.6914   -0.6902   -1.2794  0.0000
  Disp. Coeff #1 * 2856.960  2896.561  2933.527  2968.578  3003.310 823.907
  Disp. Coeff #2 * 0.076746  0.076004  0.075101  0.074407  0.073260 0.077476
  Disp. Coeff #3 *-0.725E-6 -0.739E-6 -0.734E-6 -0.751E-6 -0.707E-6 -0.726E-6
*************************************************************************

ETC Values      :     O3 =     1690   ;     SO2 =      215

O3 Absn Coeffs  :     O3 =   0.3446   ;     SO2 =   1.1533
SO2 Absn Coeffs :     O3 =        0   ;     SO2 =   2.3500

Micrometer steps/deg     =     0.00   WL cal step number       =   286
Micrometer Zero          =     2469   Umkehr offset            =   1688
Iris Open Steps          =      250   Zenith steps/rev         =   2972

Micrometer 1 Offset O3   =        0   Micrometer 2 Offset      =        0
Grating Slope            =        1   Grating Intercept        =       10
Filterwheel 3 Offset O3  =      242

Dead Time(ns)            =   40       Buffer Delay(s)          =      0.6
Zenith UVB Dome Position =   2223
Note:  Faster Processors May Require a Longer Buffer Delay
               (Typically 0.2 to 0.8 Seconds)
```

Average files: ???AVG.nnn and OZOAVGYY.nnn

The Brewer is a 'statistical' instrument, and instantaneous deviations from the norm are not uncommon. The purpose of average files is to provide a daily value for a specific measurement or test result. It is normal to plot the data in average files vs time (days) to observe trends in data and test results.

APOAVG.nnn - Analog Printout Log
The values should be monitored for power supply stability.

1	2	3	4
08591	1566.80	5.17	1.61
08691	1555.86	5.17	1.61

1. Julian Day (dddyy)
2. H.T. voltage
3. +5V
4. standard lamp current

DTOAVG.nnn - Dead Time Log

1	2	3
04991	41.66	43.375
05991	41.69	43.276

1. Julian Day (dddyy)
2. dead time for high intensities
3. dead time for low intensities

FMOAVG.nnn - FM Average

1	2	3	4	5	6	7	8	9
05791	425.9	+4.8	3152.5	-0.2	1.3	189001.4	4	33
05891	403.1	+5.3	2909.1	2.6	4.8	1788953	3	34

1. Julian Day (dddyy)
2. daily mean ozone
3. standard deviation of daily mean ozone
4. ETC
5. daily mean SO_2
6. standard deviation of daily mean SO_2.
7. ETC,
8. number of good observations
9. number of total observations.

H2OAVG.nnn Humidity Log File

The file is updated during the AP command at the End-of-Day.

1	2	3	4	5	6
29098	23.939	21.186	24.793	3.60	19.4
29198	25.648	25.458	25.078	2.68	11.3

1. Julian day (jjjyy)
2. Temperature at the PMT (°C)
3. 'Fan' Temperature in °C - used in the absolute humidity calculation.
4. Temp of base plate (°C)
5. Moisture measured in grams of water per cubic meter of air.
6. Relative Humidity (%)

HGOAVG.nnn

1	2	3	4
08391	2592	33	18
08491	2330	25	20
08591	2483	34	22

1. Julian Day (jjjyy)
2 maximum lamp intensity of the days scans
3. high Brewer temperature of the days scans
4. number of scans.

MIOAVG.nnn - Micrometer Log

A new entry is generated each time the FR routine is run.

1	2	3	4	5	6	7
33898 o_3	28	286	-2	0	0	0
33998 o_3	27	286	0	0	0	0
34098 o_3	26	286	0	0	2	0

1. Julian day followed by O_3 to indicate this is an ozone operation
2. Temperature at time of test
3. wavelength offset step number
4. Micrometer #1 steps from operating position to zero sensor.
5. Micrometer #1 offset constant from the ICF file.
6. Micrometer #2 steps from operating position to zero sensor.
7. Micrometer #2 offset constant from the ICF file.

OPAVG.nnn -- Operating Constants Log

Used to keep a record of changes to the operating constants used in the Brewer.
Updated during the ED or when the CF or IC routine is used.
The first column of the file is the routine that generated the entry in the operating constants log (IC, CF or ED). The rest of the entries are identical to the OP_ST.nnn file. See Appendix B.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ED	159	c:\bdata\	icf31098	zsf13998	dcf11798	07	12	98	Saskatoon	52	107	1000	3.220544
IC	159	c:\bdata\	icf31098	zsf13998	dcf11798	07	12	98	Saskatoon	52	107	1000	3.286822

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
10	0	14696	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	Skc	o_3	epa96	03:31:16
10	0	14696	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1		o_3		19:43:56

OZOAVGYY.nnn - Ozone Average File

Used to monitor the daily average ozone measurements collected by the Brewer

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
08398	452.1	+2.4	-0.6	0.6	16/29	185	20	445.2	+5.2	-12.3	26.4	19/22	199	19
08498	472.8	+2.1	-.08	1.2	22/35	185	19	465.5	+5.8	-7.3	25.1	16/20	190	19
08598	458.8	+9.3	-0.7	0.6	12/35	192	18	461.7	+7.2	-5.7	23.2	16/20	184	19

Direct Sun (DS) Ozone Data

1. julian day & year
2. mean daily total column DS ozone
3. DS ozone standard deviation
4. mean daily total column DS sulphur dioxide
5. DS SO_2 standard deviation
6. number of good DS observations / number of total DS observations
7. harmonic mean of airmass for the DS measurements.
8. hour that best represents the mean time for the mean DS daily ozone

Zenith Sky (ZS) Ozone Data

9. mean daily total column ZS ozone
10. ZS ozone standard deviation
11. mean daily total column ZS sulphur dioxide
12. ZS SO_2 standard deviation
13. number of good ZS observations / number of total ZS observations
14. harmonic mean of airmass for the ZS measurements.
15. hour that best represents the mean time for the mean zs daily ozone

FZOAVG.nnn

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
17897	326.3	+11	-3.1	+1.2	31/	77	192	12	44.7	+13.5	-28.6	+12.8	7/	7	508	8
17997	342.3	+3.3	-3.1	+1.0	13/	56	179	13	0.0	+0.0	+0.0	+0.0	0/	3	0	0
18097	323.6	+2.9	-2.9	+0.9	9/	55	190	14	332.6	+0.8	-25.3	+6.8	2/	5	556	12

1. Julian day
2. DS ozone
3. Standard deviation
4. DS SO_2
5. Standard deviation
6. Good Observations
7. Total Observations
8. Harmonic mean of mu
9. Representative hour
10. FZ ozone
11. Standard deviation
12. FZ SO_2
13. Standard Deviation
14 Good Observations
15. Total Observations
16. Harmonic mean of mu
17. Representative hour

RSOAVG.nnn - Run / Stop Log

Used to monitor the operation of the slitmask. The values of colums 2,4,5,6,7,8, and 9 should be 1±0.003

1	2	3	4	5	6	7	8	9
08391	1.0006	1.1667	1.0003	.9995	1.0005	.9999	.9991	.9997
08491	1.0020	.9024	.9989	.9994	1.0001	.9992	.9998	.9996

1.dddyy
2-9 run/stop ratio for slit mask positions 0 through 7.

SCOAVG.nnn - Sun Scan Average File

1	2	3	4	5	6	7	8	9
07590	22	1.971933	1	133.6	440.1	131.7	-.3	135
07991	21	1.889433	2	134.5	418.1	131.3	.1	137
08791	30	1.804133	2	136.9	404.7	133.6	-.6	135

1. dddyy
2. temperature
3. airmass
4. neutral density filter used
5. maximum step of scan
6. Maximum Ozone
7. Minimum step of scan
8, Minimum SO_2
9. HG calibration point

SLOAVG.nnn - Standard Lamp Log

Used to monitor the stability of the Brewer's ozone measureing stability..

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
06791	14	32	5	1705	815	-29	-702	3952	2023	581925	1	1	1	2	4	2	10848
06891	24	35	4	1707	815	-29	-703	3957	2026	572599	4	2	2	1	1	1	6619
06991	25	31	2	1706	815	-30	-700	3948	2021	576789	1	1	0	1	2	1	6873

1. dddyy
2. low temperature of the SL test
3. high temperature of the SL test
4. number of sl tests
5. ratio 1
6. ratio 2
7. Ratio 3
8. Ratio 4
9. Ratio 5
10. Ratio 6
11. Lamp intensity

12-18. Standard Deviations

DUVJJJYY.nnn: Gives the Daily DUV.

Time	DUV
6.1860	4.402109
8.5610	65.338420
9.8725	132.457100
12.7702	219.891700
15.7105	105.198000
16.3337	69.199570
17.1518	40.585530
17.9707	16.680470
18.7878	5.160622
19.6043	0.597062

Time is in decimal hours from 00:00:00 GMT
DUV is in $mW/m^2/nm$

UVOAVG.nnn

1	2	3	4	5	6
20898	2073.4	14	21	20	uvr13398.159
20998	3559.2	14	27	20	uvr13398.159

1. Julian day and year
2. daily weighted Diffey UV, Joules
3. length of day; hours between the first and last scan in the UV data file
4. the number of scans in the UV file
5. representative hour
6. UVRJJJYY file in use

UVBJJJYY.nnn: produced from UV scans by AB_UVDAT.EXE
First row - decimal hours from 00:00 (GMT)
First column - wavelength (angstroms)
Other columns : one per scan taken - irradiance ($W/m^2/nm$)
Second last row - scan weighted (Erythema) UV (mW/m^2)
Last row - scan weighted (Diffey) UV (mW/m^2)

DUVJJJYY.nnn: produced from UV scans by AB_UVDAT.EXE)
First column - decimal hours from 00:00 (GMT)
Row 1 column 2 - daily weighted (Erythema) UV (J/m^2)
Row 1 column 3 - daily weighted (Diffey) UV (J/m^2)
Remainder of column 2 - scan weighted (Erythema) UV (mW/m^2)
Remainder of column 3 - scan weighted (Diffey) UV (mW/m^2)

LAMP_LLL.nnn - Lamp File
The Lamp file is created at the factory by an initial Quick Scan.
Subsequent QS scans append data to LAMP_LLL.nnn, using the first line as a reference.

Column	Description
1	Julian date
2	Distance from lamp filament to teflon diffuser
3	pmt temperature
4	Dark count
5-15	Intensities at 11 wavelengths
16	DUV calculation based on the lamp intensities

QL_LLL.nnn - Lamp File

The Lamp file is created at the factory by an initial Quick Lamp Scan.
Subsequent QL scans append data to QL__LLL.nnn, using the first line as a reference.

Column	Description
1	Total amount of wavelengths measured
2	Julian date
3	Distance from lamp filament to teflon diffuser
4	pmt temperature
5	Dark count
6	Average percentage deviation compared to top reference measurement
7-30	Corrected intensities at 12 wavelengths (for MKII)
31	Time scan finished (for MKII)
7-54	Corrected intensities at 24 wavelengths (for MKIII and MKIV)
55	Time scan finished (for MKIII and MKIV)

LAMPLLL.IRX - Lamp Irradiance File

Lamp Irradiance files, generated at the factory, tabulate the UV irradiance of the UV test lamps.

First row - lamp identification number
Second row - distance between lamp filament and teflon diffuser
Now the file splits into 2 columns:
First column - wavelength in Angstroms from 2865A to 3630A in 0.5nm Increments.
Second column - irradiance in milli watts per square metre.

PUX, PUF, PUV, PUA: Processed UV files
First row - decimal hours from 00:00 (GMT) Header for each scan includes date, starting time (hour), ending time (hour), zenith angle, latitude, longitude, location name, instrument # and measurement type, Row 2 column 1 - GMT time in minutes, column 2 - Wavelength (Angstroms), column 3 - irradiance ($W/m^2/nm$ or $mW/m^2/nm$, depending on selection during processing).

PXL: Processed lamp files
First row - Lamp Number
Row 2 - distance in centimeters
Column 1 Row 3 - Wavelength (Angstroms)
Row 4 - irradiance ($mW/m^2/nm$)

APPENDIX B CONFIGURATION FILES

ICFJJJYY.nnn - Instrument Constants

#	Example	Name
1	0	Ozone temperature coefficient for slit 1
2	-.2473	Ozone temperature coefficient for slit 2
3	-.6914	Ozone temperature coefficient for slit 3
4	-.6902	Ozone temperature coefficient for slit 4
5	-.2794	Ozone temperature coefficient for slit 5
6	0	Micrometer steps per degree
7	.3446	Ozone on ozone ratio
8	2.35	SO_2 on SO_2 ratio
9	1.1533	Ozone on SO_2 ratio
10	1690	ETC on ozone ratio
11	215	ETC on SO_2 ratio
12	4E-08	Dead time (seconds)
13	286	Wavelength calibration step number
14	14	Slit mask motor delay
15	1688	Umkehr offset
16	0	Neutral density of filter 0
17	5000	Neutral density of filter 1
18	10000	Neutral density of filter 2
19	15000	Neutral density of filter 3
20	20000	Neutral density of filter 4
21	25000	Neutral density of filter 5
22	2972	Zenith motor steps per revolution
23	Mkiii	Brewer model type
24	1	COM port number
25	0	ozone temperature coefficient for mercury exit slit
26-31	-	Not Used
32	0	ozone micrometer #1 offset
33	2310	ozone micrometer #2 offset
34-40	-	Not Used
41	.998	grating slope
42	1.901	grating intercept
43	2469	Micrometer zero position
44	250	number of motor steps to open iris
45	0.8	Computer buffer delay (larger numbers for faster computers)
46	-	Not Used
47	256	ozone filterwheel #1 position
48	0	filterwheel #2 position
49	64	UV filterwheel #2 position
50	40	steps from zenith sensor to the hard stop
51	2223	Zenith UV position
52	1 Jan 99	Release Date

OP_ST.nnn - Operating State File

The operating state file controls many of the operating parameters of the Brewer. The left column lists the actual value written in the OP_ST.nnn file. The middle column is the BASIC variable name used in the Brewer software to contain this value, and the right column is a description of the value's meaning.

#	Sample	SW Variable	Explanation
1	046	NO$	Brewer ID number
2	\BDATA	DD$	Data Directory
3	ICFjjjyy	ICF$	instrument constants file
4	ZSFjjjyy	ZSF$	zenith sky coefficients file
5	DCFjjjyy	DCF$	dispersion constants file
6	UVRjjjyy	UVR$	UV response file
7	01	DA$	Current day
8	01	MO$	Current month
9	99	YE$	Current year
10	Saskatoon	LO$	Location of Brewer instrument
11	52.108	L1$	Latitude of instrument
12	106.713	L2$	Longitude of instrument
13	960	L3$	Average climatic station pressure (millibars)
14	1.8	TE$	Voltage representation of Brewer temperature
15	215	NC%	Azimuth north correction
16	0	HC%	Zenith horizon correction
17	14689	SR%	Azimuth steps per revolution
18	1	Q1%	Zenith drive motor
19	1	Q2%	Azimuth drive motor
20	1	Q3%	Iris drive motor
21	1	Q4%	Filterwheel #1 drive motor
22	1	Q5%	Filterwheel #2 drive motor
23	1	Q6%	Clock board
24	1	Q7%	A/D board
25	1	Q8%	UVB port
26	1	Q9%	Filterwheel #3 drive motor
27	1	Q10%	New or old temperature circuit. Set to 1 for a new temperature circuit and 0 for an old circuit.
28	1	Q11%	Second film polarizer
29	0	Q12%	Set to 1 to enable NOBREW operation
30	1	Q13%	Wide HG slit present. Always set this to 1.
31	1	Q14%	New Brewer electronics board
32	0	Q15%	Humidity Sensor
33	skc/menu	DI$	Schedule or menu indicator
34	O_3	MDD$	Mode
35	UMKNO2	SK$	Schedule name

DCFJJJ.nnn - Dispersion constants

The Dispersion Constants are used to calculate the ozone wavelength of the exit slits.

#	Example	Name
1	Disp	Header
2	2856.96	intercept for slit 1
3	7.674577E-02	slope for slit 1
4	-7.251786E-07	quadratic for slit 1
5	2896.561	intercept for slit 2
6	7.600413E-02	slope for slit 2
7	-7.387072E-07	quadratic for slit 2
8	2933.527	intercept for slit 3
9	.0751006	slope for slit 3
10	-7.337653E-07	quadratic for slit 3
11	2968.578	intercept for slit 4
12	7.440717E-02	slope for slit 4
13	-7.512483E-07	quadratic for slit 4
14	3003.31	intercept for slit 5
15	7.325987E-02	slope for slit 5
16	-7.065609E-07	quadratic for slit 5
17	2823.907	intercept for mercury exit slit
18	.0774763	slope for mercury exit slit
19	-7.259538E-07	quadratic for mercury exit slit
20-36	-	Not used

UMKSETUP.nnn - Umkehr setup file

#	Example
1	SXUNI4M.DAT
2	STDTABS.DAT
3	O3TABLE.DAT
4	CQMS.DAT
5	4.1099 2.3155 1.5600 0.8637
6	0.6760 0.3187 0.1490 0.0776 .. ozone coefficients for #039 STN TMO
7	3 6 11 12 1 1.0 812.0
8	999 1 34.838 0
9	0 ... debug file

1 - 4. Tables used in the calculation of Umkehrs.
5 - 6. Ozone coefficients
7. This line has 7 parameters:
    1 Minimum starting zenith angle
    2 Maximum starting zenith angle
    3 Minimum ending zenith angle
    4 Maximum ending zenith angle
    5 Output control flag
    6 Ozone scaling factor (used with Dobson data)
    7 Surface pressure of the station (in mmHg)
8. This line has 4 parameters:
    1 Station identifying number (3 digits)
    2 Parameter no longer used (set to 1)
    3 Latitude of station - used for first guess
    4 Output control flag (set to 0)
9. Flag for debugging purposes only.

UVRJJJYY.nnn
First column: wavelength in Angstrom.
Second column is responsivity in counts/mW/m^2/nm.

ZSFJJJYY.nnn (ZSFVAL)- Zenith Sky Constants
Zenith Sky constants are used in the ZS ozone calculations, and are Location/Brewer dependent. They are derived by making a comparison of near simultaneous DS and ZS measurements over a wide range of mu and ozone values (usually many months).
The values supplied in ZSFVAL.nnn are for a Brewer #035 operating in Toronto, Canada, and will produce results which are accurate to within 5% or so. These values can be used until a new set can be derived for the new site.

Example	Name
Zeni	Header
-.0064	Coefficient #1
-.01968	Coefficient #2
.01654	Coefficient #3
.194706	Coefficient #4
.280512	Coefficient #5
-.061317	Coefficient #6
-.490686	Coefficient #7
.456243	Coefficient #8
-.045191	Coefficient #9

APPENDIX C UV PROCESSING

LAMP DATA ANALYSIS

Brewer Response Files

RESIII.EXE is used to determine the responsivity of a Brewer with the aid of data from a calibrated external tungsten-halogen lamp. Requirements for program execution are a LAMP_LLL.IRX file for each lamp used, and the XL or UL file, XLJJJYY.nnn. The output of this program is a new response file. It is recommended that the new response files be named with the format UVRJJJYY.nnn. This file should be compared to previous response files to determine if there has been a possible change in the performance of either Brewer electronics or optics. The response file is similar to the SL test results for keeping track of instrument stability. The response file is also accessed by the UV and UVSUM routines and AB_UVDAT to calculate a damaging ultra-violet (DUV) amount for each scan and for the day. The most representative response file should be kept in the Brewer data directory C:\BDATA\NNN.

To use RESIII.EXE, it should reside in a directory containing the XL scans and the Lamp irradiance files.

1. The program is launched by typing “RESIII”
2. At the prompt, the instrument number is entered.
3. All lamp files and XL scans matching that instrument are read into a list. The list shows all scans - any scans that do not have a lamp file available are marked with a (!)
4. The scans to be processed are selected by ranges and lists of numbers (ie. "2,5-7,12", results in scans 2,5,6,7, and 12 to be processed. Scans that have no lamp files are skipped.
5. If a new response file is desired, the filename of the new file is entered in the form form UVRJJJYY.NNN
6. The new response file is placed in the C:\BDATA\NNN directory, and replaces the old RES file in OP_ST.NNN.

The response file calculated each time will be affected by temperature (lower response with higher temperatures), lamp positioning, and power supply stability. Changes from accepted response values of more than 5% should prompt investigation into the discrepancy. Statistics from the response calculations should give percent standard deviations of <1.5% to be considered acceptable.

Lamp Irradiance Files

RD_UX.EXE is used to process external lamp scans from the XL or UL routine to produce lamp irradiance files. The input files are in units of raw counts per second, the output files have units of $W/m^2/nm$ or $mW/m^2/nm$.

Instructions:

1. Create a test directory and copy RD_UX from the uv-lamp directory to the test directory.
2. Copy the UL or XL file(s) that you wish to process to the test directory.
3. Create a /nnn directory in your test directory (nnn is your Brewer number).
4. Copy the appropriate UV response file into the /nnn directory.
5. Run the RD_UX program and follow the directions given.
6. A list of all scans is displayed and the user is asked to select the scans to be used.
7. A single processed file will be prefixed by the letter "P" such as, PXLJJJYY.nnn. If individual files for each scan were requested, then individual files of the form PXLJJJSS.nnn will be produced - where SS is the sequence of the scan.
8. The P file (or files) represent the irradiance of the lamp used.

UV DATA ANALYSIS PROGRAMS

AB_UVDAT.EXE processes multiple UVJJJYY.nnn files in a similar fashion to the UV.RTN and the UVSUM.RTN except that integrated results are tabulated along with data from the individual wavelengths.

AB_UVDAT, UVSUM.RTN and UV.RTN have a UVA correction built into the weighting curves.
Calculated results represent both the UVB and UVA regions (290-400nm).
AB_UVDAT creates two data files, UVBJJJYY, and DUVJJJYY, for each UV file processed, and appends to a third file, UVOAVG.
Two action spectra, Erythema and Diffey, are used separately to weight the UV scans.
AB_UVDAT requires access to the appropriate instrument response file.

The integration technique used in UV.RTN, UVSUM.RTN and AB_UVDAT is one of histogram summation with the following properties.
The raw counts in the UV file are converted throughout to counts per second and corrected for instrument dead time.
The average of the counts recorded at wavelengths <=292nm represent a dark count (noise) value and is subtracted from all other wavelengths.
The corrected raw counts are then divided by the instrument response values and multiplied by the appropriate weighting value at each wavelength.
Scan integration is then the sum of the histograms, each 0.5 nm wide and as high as the corrected weighted irradiance.

For the UVSUM.RTN, daily irradiance integration is the sum of histograms that are as wide as the time between consecutive scans and as high as the average of the irradiance of two consecutive scans.

For AB_UVDAT daily irradiance integration is the sum of histograms that are as wide as the average of the difference of the time for the following and the previous scan and as high as the irradiance for that particular scan.

For the most representative daily integral values it is recommended that UV scans be taken throughout the daylight hours at regular zenith angle intervals.
Histogram summation starts at the time of the first UV scan and stops at the time of the last UV scan.
On a clear day without variable clouds or other aerosols the energy curve assumes a normal distribution

Using AB_UVDAT.EXE

Input:
1. A range of consecutive UVJJJYY.nnn files
2. the appropriate UV response file.

Output:
1. One UVOAVG.nnn file which tabelates the average values from the other output files.
2. One UVBJJJYY.nnn file for each input file.
3. One DUVJJJYY.nnn file for each input file.

1. Create a test directory.
2. Copy AB_UVDAT.EXE to the test directory.
3. Copy the UV response file into the test directory.
4. Copy the UV files to be processed into the test directory
5. Run AB_UVDAT follow the directions given.

UV and UX Data Analysis Programs

RD_UX.EXE is used to reduce the UV data produced by the UA, UC, UF, UV, and UX routines. The input file is in units of raw counts per second and outputs may be chosen units of in $W/m^2/nm$ or in $mW/m^2/nm$.

Instructions:
1. Create a test directory and copy RD_UX from the uv_lamps directory to the test directory.
2. Copy the UL or XL file(s) that you wish to process to the test directory.
3. Create a /nnn directory in your test directory (nnn is your Brewer number).
4. Copy the appropriate UV response file into the /nnn directory.
5. Run the RD_UX program and follow the directions given.
6. A list of all scans is displayed and the user is asked to select the scans to be used.
7. The user will then be asked whether or not to correct for stray light – the stray light correction subtracts the average of the counts below 292.2 nm from each measurement.
8. A single processed file will be prefixed by the letter "P" such as, PUVJJJYY.nnn. If individual files for each scan were requested, then individual files of the form PUVJJJSS.nnn will be produced - where SS is the sequence of the scan.
9. The PUV file (or files) represent the irradiance of the UV scans.

APPENDIX D NOBREWER

It is often useful to be able to operate the Brewer software without having a Brewer connected to the Computer.
A batch file, C:\NOBREW.BAT, has been developed which sets a number of operating parameters to make the software think that Brewer communications are taking place.

In this mode of operation a number of operations can be done:

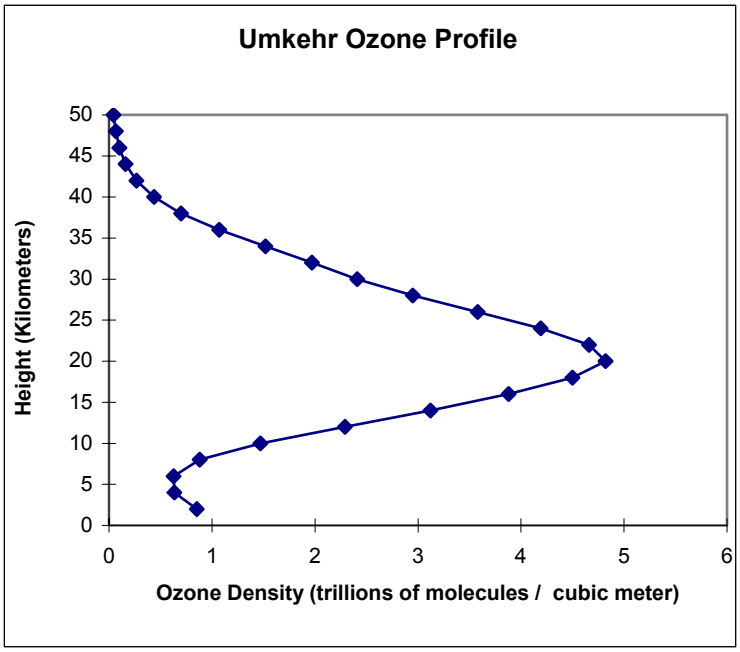
-- Schedules can be written using SE and the solar angle information can be printed using SA.
-- Dates and time can be changed as can Site Information and Brewer number.
-- Configuration , Instrument Constant, and Operating State Files can be updated and saved.

A Brewer must not be connected to the COM: port that is defined in the Configuration file and is being accessed by NOBREW.

Quite often the Brewer sotware is installed on a second computer and NOBREW is operated away from the Brewer.

APPENDIX E UMKEHR PROCESSING

Umkehr profiles show the vertical distribution of Ozone in the Atmosphere from ground level to 50 km.



Using the UM.RTN, the Brewer Spectrophotometer takes Umkehr measurements through a series of Zenith Sky samples of multiple wavelengths between solar zenith angles of 60 and 91° in the morning and in the evening.
Data is stored in the daily 'B' file and at the End of Day is written to a daily 'U' file.

Umkehr processing software, the purpose of which is to process the Brewer raw Umkehr data into graphable profiles, has been developed by Scientists at Environment Canada. This software is not a KIPP & ZONEN poduct, nor does KIPP & ZONEN claim to have expertise in the area of Umkehr processing. We will, however, endevour to provide whatever information we can to assist users in the generation of ozone profiles for their stations, and the following discussion is a first attempt.

This Appendix briefly describes the steps necessary to process Umkehr Data. For further expert assistance, especially as concerns the quality of data, and station dependent parameters, it is suggested that WMO or EC scientists be consulted.
For a more in-depth discussion of the theory and practicalities of Umkehr measurements and presentation, experts at Environment Canada or the WOUDC should be consulted.

1. Conventions: JJJYY Julian day and year
   nnn Brewer number

2. All Umkehr Data and data processing programs should reside in a common directory.

3. The main programs for processing and analysis are:

   PREPRO.EXE -- a preprocessing program
   TOMKEHR.EXE -- the Umkehr analysis program
   RUNPRE.BAT -- a batch file used to launch PREPRO.EXE
   RUNUMK.BAT -- a batch file used to launch TOMKEHR.EXE

   The proper execution of PREPRO.EXE and TOMKEHR.EXE requires that the following files also be present:

   UJJJYY.nnn -- Brewer Umkehr data file to be analyzed
   OZOAVGYY.nnn -- daily average ozone value file

   SXUNI4M.DAT
   STDTABS.DAT
   O3TABLE.DAT
   CQMS.DAT

   PRESETUP.nnn -- a file containing station data which is created by using a text editor to modify a sample file such that it contains:
   -- the ozoavg file to be used
   -- the station number, station code, latitude, longitude

   UMKSETUP.nnn -- a file created during the Brewer calibration containing pointers to the above .DAT files, ozone coefficients, and sun angle information.
   -- must be edited to include as line 7 the following: 3,6,11,12,1,1.0,pressure, where pressure is mean station pressure in millibars

4. The batch file RUNPRE.BAT will invoke PREPRO.EXE and set the necessary parameters when the command line RUNPRE JJJYY.nnn is issued.

5. Three files are created following the successful execution of PREPRO:

   UPJJJYY.nnn -the preprocessor output listing
   UDJJJYY.nnn -output data to be used by the analysis program
   UGJJJYY.nnn -reduced data

6. The batch file RUNUMK.BAT sets up and runs TOMKEHR.EXE when the command line RUNUMK JJJYY.nnn is issued.

7. Successful execution of TOMKER results in the creation of three files:

   USJJJYY.nnn
   UOJJJYY.nnn
   UNJJJYY.nnn suitable for graphing the ozone profile.

Some useful information on the Umkehr processing software and its use may be found in the following three documents written by Dr. T.C. McElroy:

-- Umkehr Inversion Algorithm for the Brewer Ozone Spectrophotometer
-- Readme.Doc
-- Readme.V3

Copies of these documents are available from the World Ozone and UV Data Centre (WOUDC) website.

APPENDIX F FACTORY TESTS

SETUP AND CALIBRATION TESTS

The tests and calibration techniques described here are essentially those performed by the factory before the Brewer Spectrophotometer is shipped. [Refer to the Final Test Record for the set of test results, graphs, and derived constants for a specific instrument.] Some of these tests (HV, SH) would only be performed by the user after repair or replacement of one or more of the instrument's optical or mechanical components. In contrast, the HG (mercury-line calibration) and SL (standard lamp) tests should be performed at least once per day. The remaining tests should be carried out at approximately monthly intervals to verify correct instrument performance.
The order in which these tests are described is significant. Tests which follow later in the sequence assume that the earlier tests and calibrations have been successful. A complete instrument recalibration (a task not to be undertaken lightly) would therefore follow the ordering implied in this section.
Table F-1 summarizes the settings of the Brewer's controllable elements for each of the setup tests. The software will automatically set the elements to where they should be for a specific test. All of the following tests assume that the spectrometer is in focus and properly aligned in accordance with the Optical Frame Alignment document.

Table F.1: Settings for Brewer Tests

Test	Wave-Length	Slitmask Motor Position	Std Lamp	Hg Lamp	Filter Wheel 1	Filter Wheel 2	Iris	Prism	Azimuth Tracker
DT	Ref	3,5,7	On	Off	1	0,1	Open	180°	N/A
HG	Estab Ref	0	Off	On	1	0	Open	180°	N/A
HV	Ref	1,2	On	Off	1	0	Open	180°	N/A
RS	Ref	0-7	On	Off	1	0	Open	180°	N/A
SC	Ref	0-6	Off	Off	1	0,1,2	Close	Point at sun	Point at sun
SH	Ref	0-2	On	Off	1	0	Open	180°	N/A
SL	Ref	1-6	On	Off	1	0	Open	180°	N/A
SR	N/A	N/A	Off	Off	N/A	N/A	N/A	N/A	0°-360°

SH SHUTTER-MOTOR (SLITMASK MOTOR) TIMING TEST

The SH test determines the optimum value for the timing constant used in the control of the slitmask motor.
Measurements of the Dark Count, and light intensity of the tungsten-halogen (standard) lamp are taken through the HG and Wavelength 1 slits for a range of motor-delay constants. Observations are typically made over a range of 20 different values for the delay constant.

Method:
Send the PDHPHG command sequence to the Brewer, wait for the tests to finish.
The SH command is entered to start the slitmask-motor timing test. The program prompts for the minimum, maximum, and increment for trial values of the delay constant. Typical values are a minimum value of 2, a maximum of 30, and an increment of 2. After a five-minute lamp warm-up period, the program performs a series of intensity measurements for each trial value of the timing constant, then prints the measurements in tabular format. The following information is contained in the printout:

DELAY	CAL	DARK	WAVELENGTH 1
2	838674	162992	52984
4	1737756	32765	91539
6	1761988	15366	92076
8	1738607	10860	92448
10	1737768	7557	92828
12	1738031	480	93450
14	1737408	39	93100
16	1738864	37	93422
18	1738388	44	93318
20	1737191	28	93579
22	1738692	36	93580
24	1742088	40	93713
26	1737650	34	93666
28	1737937	32	93596

Dark Count versus Slitmask Delay should be plotted and compared to the plot shown in the Final Test Record. The optimum slitmask delay time is that which minimizes the dark count - typically this delay constant would lie within the range 10 to 16. For the table above the optimum delay constant is 14.
The new delay constant should agree with the final test record value within an acceptance tolerance of ±5. If the new constant is significantly different from the final test value then the factory should be contacted before changing the configuration in the firmware since a complete instrument re-calibration may be necessary.

HV: HIGH VOLTAGE TEST

The HV test determines the optimum high-voltage setting for the PMT.
This test requires access to the High voltage module and the front of the Main Electronics Circuit Board.
Measurements of the apparent light intensity of the quartz-halogen (standard) lamp are taken through slitmask positions 1 and 2 (dark count, and wavelength 1) for a range of high voltages.
Prior to starting the test, locate shorting plug J2 on the High Voltage Module.

Method:

1. Turn off Brewer power

2. On the High Voltage module change jumper J2 from Pins 2-3 to Pins 1-2, and restore Brewer power.

3. Enter the **HV** command, and at the prompts, enter the PMT number, the preamp discriminator level, the minimum, maximum and incremental voltages for the test. For the PMT serno. and voltage settings see the Final Test Record.

   WARNING: *A photomultiplier, which is subjected to a too high voltage, may lead to irreversible damage of the PMT and/or can decrease its lifetime. The maximum allowable voltage is PMT specific. It is therefore recommended not to exceed the voltages for your PMT as mentioned in the Final Test Record.*

4. The Standard Lamp is turned ON, FW#1 is put to Position 1, FW#2 to Position 0, the Iris is opened, and the zenith prism turned to the lamp housing.

5. Following a 5 minute lamp warmup, the test runs, and data is written to the DJJJYY.nnn file and to a HVJJJYY.nnn file.

Table F-2 : Typical photomultiplier response output

Photomultiplier S/N 10256 Preamp voltage level:10

Control voltage	Dark Count	Wavelength 1	Ratio	Actual voltage
750	9	10	3	747.2
761	4	10	5	757.3
771	4	15	8	769.3
782	5	25	11	781.3
792	6	49	20	791.3
803	3	79	46	803.4
813	2	238	168	813.4
824	3	648	374	825.4
834	4	1814	907	837.4
845	4	4466	2233	847.5
855	8	9244	3268	857.5
866	4	16883	8442	869.5
876	5	27775	12421	879.5
887	7	40973	15486	891.5
897	6	55779	22772	901.6
908	10	71077	22477	911.6
918	9	86191	28730	923.6
929	8	99579	35206	933.6
939	17	111900	27140	943.7
950	9	122532	40844	955.7
960	11	131484	39644	965.7
971	14	138978	37143	975.7

981	18	144932	34161	985.7
992	17	149962	36371	995.8
1002	15	153943	39748	1007.8
1013	18	157825	37200	1017.8
1023	19	160926	36919	1027.8
1034	19	163407	37488	1037.9
1044	22	165796	35348	1049.9
1055	19	168082	38561	1059.9
1065	24	170292	34761	1069.9
1076	25	172626	34525	1082.0
1086	26	175036	34327	1092.0
1097	29	177199	32905	1102.0

6. A plot of the dark count and wavelength 1 intensity values vs the high voltage should be compared to the plot in the Final Test Record.
The wavelength 1 data should exhibit a region of minimum slope (plateau).
The optimum setting for the high voltage is at the beginning of the plateau. The ratio is determined by deviding the counts of wavelength 1 by the square root of the dark count.

If the new established optimum high voltage value deviates approximately 50 Volts or more from the orignial setting then it is desired to change the current setting. See the HVSET explanation on how to adjust the high voltage.

WARNING: Changing the high voltage for the photomuliplier may effect the ozon calibration, but will change the UV calibration for sure. The best time for adjusting the high voltage is therefore during re-calibration of the Brewer instrument.

HVSET: Set PMT High Voltage
HVSET is used to set the PMT High Voltage as determined from the HV test.
This test requires access to the High voltage module and the front of the Main Electronics Circuit Board.
Prior to starting the test, locate shorting plug J2 and potentiometer R4 on the High Voltage Module, and test point E16 on the Main Electronics Board.

Method:
1. If not already done so, then turn off Brewer power and on the high voltage module move jumper J2 from Pins 2-3 to Pins 1-2, and restore Brewer power.
2. Enter the **HVSET** command and enter the desired HV value at the prompt.
3. Measure the voltage at E16 on the Main Electronics PCB and write the value down.
4. Turn off Brewer power and set jumper J2 back to pins 2-3, and restore power.
5. Monitor E16 and adjust R4 on the High Voltage Module until E16 is set to the voltage as recorded in step 3.
6. Confirm the setting with an AP command.

RS: SLITMASK MOTOR RUN/STOP TEST

The RS test verifies that the slitmask motor (slitmask motor) is operating correctly.
In the normal, or "dynamic" mode of operation the slitmask is cycled rapidly, permitting individual measurements to be made at intervals of 131 milliseconds. To ensure that the light intensities are being properly measured in this dynamic mode, the RS test also measures intensities in a "static" mode. Light passing through each slit is measured for a longer period of time during which the slitmask motor is stationary.
Type RS. This test runs for approximately 10 minutes, including a five-minute warmup time for the standard lamp. No further operator interaction is required. Results will be printed in a format similar to the following:

Table F-3 Typical Slitmask Test Results

POSITION	0	1	2	3	4	5	6	7
RUN	234503	54	1760383	1681139	1704288	1529450	1313677	3062937
STOP	234100	55	1760880	1682069	1704610	1531027	1313654	3063356
RUN/STOP	1.0017	0.9818	0.9997	0.9994	0.9998	0.9990	1.0000	0.9999
RATIOS (RUN)			-0.036	-0.0319	-0.0586	-0.99	0.2808	0.1657
RATIOS (STOP)			-0.0346	-0.0306	-0.0564	-0.1005	0.2872	0.1682

The test is deemed successful if the ratio RUN/STOP for the five operational wavelengths (slitmask positions 2..6) are in the range 0.997 to 1.003, and if the ratio for dark count (position 1) lies within the range 0.20 to 5.0. If the ratios fall outside the acceptance range, there may be problems with either the slitmask alignment, the slitmask-motor power supply or drive circuitry, or an improper motor timing constant may have been stored in the instrument Constants File (refer back to the slitmask-motor timing test, SH).
Normal operational ratios (R1 - R6) are printed out in the last two lines so that ratios in the dynamic (RUN) and static (STOP) modes can be compared.

DT: PHOTOMULTIPLIER DEADTIME TEST

The DT test measures the deadtime of the photomultiplier and photon-counting circuitry. This test takes readings at four slitmask positions:

Slitmask Position	Description	BASIC Variable
1	Darkcount	F(1)
3	Wavelength 2	F(3)
5	Wavelength 4	F(5)
7	Wavelength 2&4	F(7)

Position 7 allows simultaneous observation through slits 3 and 5. Dark count-corrected counts are stored in the BASIC F() array (refer to the Preliminary Data Reduction document for details). The following algorithm is used to derive a value for instrument deadtime:

Assume Poisson statistics:

$$N = N_0 \cdot e^{-N_0 \cdot \tau}$$

$$\tau = \frac{1}{N_0} \cdot \log_e \left(\frac{N_0}{N} \right)$$

where:

N_o is the true count-rate (counts/sec),
N is the observed count-rate,
τ is the deadtime (sec). (The BASIC variable T1 is used for τ .)

1. As a first approximation set the true (unknown) count-rates equal to the observed count-rates:

$$F_3' \leftarrow F_3$$

$$F_5' \leftarrow F_5$$

2. Compute an estimate for deadtime:

$$\tau \leftarrow \frac{1}{F_3' + F_5'} \cdot \log_e \frac{F_3' + F'}{F_7}$$

3. Revise the estimates for the true count-rates:

$$F_3' \leftarrow F_3 \cdot e^{F_3' \cdot \tau}$$

$$F_5' \leftarrow F_5 \cdot e^{F_5' \cdot \tau}$$

4. Iterate steps 2 and 3 until the value for T1 converges.

Deadtime measurements are made at both high and moderate light intensity levels by using two different neutral-density filter settings (positions 0, 1 for Filterwheel #2); five measurements are taken at the higher intensity, ten at the lower intensity.

Method:
The command DT is issued.
Following the usual five minute lamp warm-up, and a further 10 minutes for test to run, results will be printed in a format similar to the following:

FILTER #1/1 AND FILTER #2/0

GMT	DEADTIME
191054	4.94288936E-08
191119	4.81299056E-08
191143	4.93662915E-08
191208	4.91343971E-08
191233	4.84666031E-08

48.705 ± .6

FILTER #1/1 AND FILTER #2/1

GMT	DEADTIME
191424	4.48950597E-08
191449	4.58755779E-08
191513	4.49521729E-08
191538	4.67340357E-08
191603	4.49957964E-08
191627	4.81735377E-08
191652	4.55349271E-08
191716	4.51368558E-08
191741	4.53192958E-08
191805	4.58533414E-08

45.747 ± 1

Following each block of measurements the deadtime mean and deadtime standard deviation (in nanoseconds) are calculated and printed. The high- and low-intensity deadtime means should agree (within an acceptance tolerance of two standard deviations), and should lie in the range 35 to 50 nanoseconds. Failure to meet this criterion indicates possible difficulties with either the slitmask motor operation, the high-voltage circuitry, or photon counting circuitry.
This newly determined deadtime constant should not be entered into the instrument Constants File unless it is significantly different (by more than about 5 ns) from the old value (if you are confident that the instrument is currently running properly). You should contact the factory before altering the stored constant since a complete recalibration may be required.

HG: MERCURY-LINE WAVELENGTH CALIBRATION

The HG test precisely locates the mercury line-spectrum, then repositions the micrometer so that the diffraction grating disperses the five operating wavelengths onto the appropriate exit slits. The test uses the mercury discharge lamp and the Hg calibration slit (slitmask position 0).
The software establishes the position of the mercury line-spectrum by scanning the micrometer forwards from step position 50 to step 280 in 10-step increments, then reversing direction and scanning from step 280 back to step 50 (note: 1 micrometer step 0.007 nm). At each position the light intensity dispersed through the calibration slit is recorded, building a 24-point profile of the mercury spectrum. This measured spectrum is compared with an internally-stored reference spectrum to determine that step position which maximizes the correlation between the measured and stored spectra. If this interpolated step number falls within the acceptance limits [147.00..149.99] the mercury spectrum is deemed to have been located, and the micrometer is moved to its operational setting (step number 286 ± 3, or 13 ± 3 micrometer steps below the mercury calibration point; this small displacement is an instrument-dependent constant known as the 'offset' stored in the instrument Constants File, and is determined by the SC test).

If, however, the mercury calibration point falls outside the acceptance range, the micrometer is reset to the newly calibrated step number and the test repeated. Iterations continue until the calibration point converges correctly.

Method:
The command HG is issued.
The program will read and display the current Brewer temperature, and a checklist of required foreoptic settings will then be displayed:

*** measurement procedure ***

check:

1 - filter #1 to position #1
2 - filter #2 to position #0
3 - open iris
4 - rotate director prism to lamps
* press return when ready *

These controllable elements will be set automatically.
After a five-minute lamp warm-up period the program will perform a series of intensity measurements over a micrometer step-number range of 50 to 280 as described earlier. The photon count for each observation point is displayed on the screen. You should observe a peaking trend as the micrometer passes through step position 150 (sample number 15). When the micrometer has completed its there-and-back journey the program computes and displays the five correlation coefficients corresponding to attempted curve matchings (between the measured spectrum and the internally-stored reference spectrum) at step positions 110, 130, 150, 170, 190. From these measurements the mercury calibration point is determined and printed in the following format:

Brewer Temp = 29 C (3.66 V)
190112 (.987) HG CALD AT STEP# 298.47 SET TO STEP# 286 9540

This report indicates that at 19:01:12 (C.U.T.: Co-ordinated Universal Time, also known as GMT), a maximum spectral-matching correlation coefficient of 0‘987 was obtained for an (interpolated) mercury calibration point of 298.47. The operational setting of the micrometer is arrived at by subtracting the 'offset' retrieved from the instrument Constants File (the offset is 12 in this case) from 298.47, then truncating the result. 9540 is the peak count across all 24 observation points. The micrometer is automatically repositioned to the operational point (step #286 in this case), and the test ends.

Should the interpolated calibration point fall outside the [147.00..149.99] acceptance range, the micrometer is automatically repositioned at the truncated calibration minus the offset and the test is repeated until the interpolated calibration point lies between 147 and 150. A sample printout for an HG test which converged in two iterations is shown below (the offset for this instrument is 10 steps):

BREWER TEMP = 26 C (3.52 V)
103409 (.9919) HG CALD AT STEP # 296.1 SET TO STEP # 286 60871
103651 (.9927) HG CALD AT STEP # 287.0 SET TO STEP # 286 61019

SL: STANDARD LAMP TEST

The SL test is a general quality-assurance examination of Brewer performance across the full range of operational wavelengths. An internal, well-regulated, quartz-halogen 'standard' lamp is used as the light source. This source produces a continuous light spectrum (unlike the mercury lamp which emits discrete wavelengths.) which is stable and consistently reproducible. This test should be run on a regular basis (e.g. twice daily) to establish a set of instrument performance records.

Method:
Type SL. The test runs through the same temperature and foreoptic positioning procedures described in HG, then waits the obligatory five minutes for the quartz-halogen lamp to warm up. The program then conducts seven measurement runs over the dark-count channel and the five operational wavelength channels. Each run cycles the slitmask through 20 oscillations, accumulating the photon counts in the BASIC one-dimensional F() array (described under Preliminary Data Reduction). These raw counts are printed in the following format:

Brewer Temp = 27 C (3.56 V)

	C.U.T.	CY	ZEN	MU	DRK	1	2	3	4	5
SL0	20:54:25	20	65.63	2.384	32	1102112	1052861	1066768	956627	820941
SL0	20:55:02	20	65.67	2.388	35	1101966	1054190	1067478	957870	821186
SL0	20:55:40	20	65.72	2.392	43	1102630	1053024	1067318	958662	821366
SL0	20:56:18	20	65.76	2.395	36	1101330	1054009	1068002	957890	821567
SL0	20:57:02	20	65.81	2.4	31	1101960	1053736	1068197	957257	820730
SL0	20:57:46	20	65.86	2.404	37	1102690	1052931	1067378	959002	821232
SL0	20:58:24	20	65.9	2.408	43	1102507	1053022	1067047	958135	822097

The SL0 indicates that the Standard Lamp test was performed with Filter Wheel #2 in position 0 (ie no neutral-density attenuation). CY is the number of slit-mask oscillations over which the counts were accumulated. ZEN and MU are the current solar-zenith angle and airmass respectively (these are irrelevant to the SL test and are presented for operator information only). The next six columns are the photon count totals for the dark channel and the five operational channels. When all seven measurement runs are complete the program corrects the raw photon counts for dark count, deadtime, and temperature-dependence, then prints a series of summary statistics:

20:56:22 Feb 21/85 65.763 2.395 27 C DEG SL 0

Mean1	mean5	MS(4)	MS(5)	MS(6)	MS(7)	MS(8)	MS(9)
1102170	821302	-623	-426	-488	-694	596	418
+ 483	+ 445	+ 3	+ 5	+ 5	+ 4	+ 15	+ 9

The first line shows the time, date, solar-zenith angle, airmass, instrument temperature and test identification. The second line of data displays the mean corrected count for channels 1 and 5, the single-ratios MS(4) through MS(7), and the double-ratios MS(8) (the SO_2 ratio), and MS(9) (the O_3 ratio). The derivation and interpretation of these values is detailed under Preliminary Data Reduction.
The third line of data shows the standard deviation for each of the quantities in the line above (there is no ASCII symbol for '±', hence the leading '+' sign).
The single-ratios MS(4) through MS(7) should remain reasonably constant from test to test; the allowable drifts in the SO_2 (MS(8)) and O_3 (MS(9)) double-ratios are about ±1.5%.

THERMAL TESTS

The Thermal Tests consist of a battery of diagnostics which determine the extent to which the spectrophotometer's performance is affected by temperature.
Measurements are made with the quartz-halogen (standard) lamp. Light intensity measurements are taken at a number of points which span the temperature range -10 to +40 °C. The wavelength setting must be recalibrated (via the HG command) at each new temperature before the standard-lamp intensities are measured. These intensity data are analyzed to yield the absolute temperature coefficients for each of the five operational wavelengths; the negative of each coefficient is stored in the instrument Constants File for subsequent use during data reduction.
During the course of the Thermal Tests all of the Brewer electromechanical subsystems should be thoroughly exercised, and any malfunction corrected.
The PRFILE.BAT program is used to process the data and determine the temperature coefficients for the brewer.

Method:
The instrument is placed in a chamber where the ambient temperature is set to values between -10 and +35°C. (These temperature settings cause the internal Brewer temperature monitor to register between approximately -5 and +40°C.) The temperature is set for 2 hours at +35 °C and then gradually lowered by approximately 1.1 °C per hour, taking approximately 50 hours in total. A typical command sequence send to the Brewer during this test period is PDFR(HP)HGSLSLDTRSAPW2TE100. The HP command is left out for single monochromator brewers.

After the Brewer has performed the above test sequence over the whole temperature range, the data is first analysed for operational failures and discrepancies. Special attention is given to the AP voltages, the *oavg files and the HG wavelength calibration postion right after the FR.

Use the five F() values at all the Brewer temperature settings to determine the five temperature response coefficients in the following five equations:

$$F(i) \leftarrow F_0(i) + TC(i) * T, \quad i = 2 \text{ to } 6$$

where

F(i) are the scaled, corrected count rates for slit positions 2 to 6
$F_0(i)$ = F(i) at 0 °C
TC(i) is the temperature response coeff. for the i'th operational wavelength
T is the Brewer temperature in °C.

The values of F0(i) and TC(i) are determined by linearly regressing F(i) against T. By using the negative of the TC(i) coefficients (as described in Compensating for Temperature under Preliminary Data Reduction document) the wavelength-dependent temperature response of the instrument is compensated.
Compare the TC(i) coefficients with those listed in the Final Test Manual. If the freshly determined values do not agree with those obtained at the factory you should consult KIPP & ZONEN or EC regarding the advisability of updating the instrument Constants File (CF command). Although the zero-Celsius values, F0(i), are not used by the Brewer software they should be recorded for future reference.

Change of Photomultiplier Tube (PMT):
Brewers with serial numbers up to #190 have photomultipliers manufactured by ET Enterprises Limited of the UK (previously known as Electron Tubes, Thorn-EMI and EMI). These PMTs are no longer available in a specification that meets the demands of the Brewer.

Brewers with serial numbers #191 and higher are fitted with Hamamatsu photomultipliers. These have superior performance to the ET tubes, but there is s restriction on the maximum operating temperature. The Hamamatsu PMT's have an ambient temperature operating range of 0° to +50° Celsius. When the temperature inside the instrument is higher than 50° Celsius too often, this could adversely affect the characteristics of the PMT.

Preventive measures are to be taken when the instrument is located at a site where the temperature inside the Brewer exceeds the limit of 50° Celsius. A simple solution would be to make a reflective heat shield over the front and top of the white Brewer cover (it could also extend down the back of the Brewer, but this is not necessary).

The heat shield should have a separation of about 25 mm from the cover, to allow air to circulate by wind or convection and to transport away the warmth. The heat shield can be made from

polished stainless steel or white painted aluminium or steel sheet. It should not extend over the zenith window or dome.

The Hamamatsu photomultiplier can be fitted to Brewers with serial numbers up to #190 using a retro-fit kit.

SC: SCAN TEST ON DIRECT SUN

The SC test determines the correct operational setting of the wavelength-adjusting micrometer. The program takes measurements of O_3 and $S0_2$ column amounts over an operator-specified range of micrometer positions (wavelengths) then prints reduced data for each of the positions.

Method:
Before running the SC test you should first ensure that the wavelength calibration is current: perform an HG (mercury-line calibration). Next, run a DS (direct sun) test to check that the appropriate neutral-density filter (Filterwheel #2) is in place. Type SC to begin the scan test. In response to the program prompts enter the minimum, maximum and increment for the stepper-motor step number - suggested values are 124, 148 and 2 respectively.

Plot the O_3 and SO_2 values as a function of step number.
Table F-4: O_3 and SO_2 column amounts vs. wavelength for a typical Scan Test on direct sun.

Step#	[O_3]	[SO_2]
124	328.4	6.4
126	333.4	5.0
128	336.3	3.6
130	338.4	3.2
132	341.3	2.7
134	345.3	1.7
136	346.4	2.0
138	348.0	2.3
140	344.8	3.5
142	347.1	3.9
144	344.4	5.7
146	342.6	6.9
148	338.9	9.2

The proper operational setting is that step number for which the O_3 value is a maximum; the SO_2 value should have a minimum within 1 or 2 micrometer steps of the O_3 maximum. This operational setting should be compared with the value currently stored in the instrument Constants File - if the new value is significantly different and you are confident the instrument is performing correctly then the instrument Constants File should be updated via the CF command. [Contact the factory before altering this constant since a complete recalibration may be required.]
The exact position of the peak of the O_3 value does change by 1 or 2 steps depending on the airmass and the amount of O_3 present. For best results this test should be performed at low airmass values (mu < 1.5).

INSTRUMENT INTER-COMPARISON CALIBRATION

The Instrument Inter-Comparison Calibration determines the absorption coefficients and extraterrestrial constants for the measurement of O_3 and SO_2. These constants are instrument dependent and must be determined for all instruments prior to O_3 or SO_2 measurements.
The uncalibrated instrument is compared to a certified Brewer reference by the analysis of a large number of time-coincident direct-sun O_3 observations made by the two instruments.

Method:
The method by which direct-sun O_3 and SO_2 values are derived from the raw photon counts at the five operational wavelengths is outlined in sections 2 and 3 of Preliminary Data Reduction. After corrections for dark count, deadtime, Rayleigh scattering, and instrument temperature have been applied, the O_3 and SO_2 (MS(11) and MS(10)), values are calculated using the following formulae:

$$MS(11) \leftarrow \frac{MS(9) - B1}{A1 \cdot M2}$$

$$MS(10) \leftarrow \frac{1}{A2} \cdot \left[\frac{MS(8) - B2}{A3 \cdot M2} - MS(11) \right]$$

where

MS(8)	is the weighted double-ratio for SO_2
MS(9)	is the weighted double-ratio for O_3
A1	is the differential O_3 absorption coefficient for the O_3 ratio
B1	is the extraterrestrial constant for the O_3 ratio
A2	is the relative SO_2 to O_3 absorption for the SO_2 ratio = (2.44)
A3	is the differential O_3 absorption coefficient for the SO_2 ratio
B2	is the extraterrestrial constant for the SO_2 ratio
M2	is the airmass, also referred to as MU.

The method to determine the four instrument-dependent values (A1, B1, A3, B2) for a particular instrument via the Inter-Comparison Calibration procedure is outlined below.
Many simultaneous direct-sun measurements (at least 40) are made with both the instrument to be calibrated and a reference instrument. Measurements should be taken over a wide range of airmass values (1.0 < mu < 3.0) for at least one full day of good observing conditions. The O_3 and SO_2 values (MS(11) and MS(10)) are determined from the measurements made with the reference instrument. These values, together with the values of MS(8), MS(9), and M2 valid for the instrument being calibrated are substituted into the above two equations which are rewritten as follows:

$$\mathrm{MS(9)} \leftarrow \mathrm{B1} + \mathrm{A1} \cdot \mathrm{M2} \cdot \mathrm{MS(11)}$$

$$\mathrm{MS(8)} \leftarrow \mathrm{B2} + \mathrm{A3} \cdot [\mathrm{M2} \cdot \mathrm{A2} \cdot \mathrm{MS(10)} + \mathrm{M2} \cdot \mathrm{MS(11)}]$$

Two least-squares linear regression fits are applied to these equations and the resulting two pairs of regression coefficients (B1, A1; B2, A3) are the four instrument-dependent coefficients.
As for all previous tests, consult EC or KIPP & ZONEN prior to altering any of the constants in the instrument Constants File.

AZ: ZERO THE AZIMUTH TRACKER

The AZ command re-orients the Azimuth Tracker to its zero-step position. This routine is activated automatically following a system reset (RE command). The operator should use this command if there is concern that the azimuth drive has lost track of where it is for such reasons as temporary power loss to the Tracker or other physical disturbance.
Note that the AZ routine can only be accessed if the instrument configuration (IC) is setup to include an Azimuth Tracker System.

Method:
Type AZ . The following screen display appears while the program steps the azimuth drive towards its internal optically-sensed reference flange:

```
*** zeroing azimuth
press Del to abort
```

The operator can abort the operation by pressing the DEL (delete) key; the program will return to the previously displayed menu. When the program has located the reference flange it compares the predicted and actual flange positions, then displays the step discrepancy on the screen for about 5 seconds:

```
*** discrepancy = n
AZIMUTH ZEROED AT HH:MM:SS DISCREPANCY = N
```

N will usually be a small integer lying in the range -10 < n < 10. (The Tracker stepper-motor gearing is approximately 15000 steps per revolution, so a discrepancy of 10 steps corresponds to a positional error of 0.2°). N will be much larger if the Brewer has recently been reset or if the Tracker has been physically perturbed (eg power interruption).

The Azimuth Tracker then returns to the solar azimuth and the previously active menu is displayed.

SR: AZIMUTH TRACKER STEPS-PER-REVOLUTION CALIBRATION

The SR test determines the number of steps required for the azimuth drive motor to turn the Brewer through 360° in azimuth. This test establishes the steps-per-revolution constant which is used by the Brewer program to orient the Brewer in azimuth to within ±1 minute of arc.
An opto-sensor located inside the Azimuth Tracker detects a reference flange on the stationary drive-wheel. The azimuth drive motor is 'zeroed' on this reference, then stepped forward until the flange is again detected on the next revolution. At this point the tracker has rotated exactly 360°, and the steps-per-revolution constant has been determined.
The SR routine can only be accessed if the instrument configuration (IC command) has been setup to include an Azimuth Tracker.

Method:
Type SR to initiate the steps-per-revolution test. The first portion of the calibration proceeds exactly as for AZ . Once the internal optically-sensed reference flange has been detected, the azimuth step-count is set to zero and the drive motor is stepped forward until the flange is again detected after 360° of rotation. During the forward search the following screen message is displayed:

```
*** finding az steps/rev
press del to abort
```

It takes approximately 30 seconds to rotate through 360°. (The operator may abort the steps-per-revolution calibration at any time by pressing the DEL key.) Calibration results are displayed as follows:

```
steps/rev measured at 14675
old value = 14678
do you want new value saved? - y/n
```

Enter 'y' if you want to update the calibration value; type 'n' if you feel the test was unsatisfactory for any reason or if the value hasn't changed. A timestamped calibration record will be printed:

AZ STEPS/REV = 14675 AT HH:MM:SS

The Azimuth Tracker then returns to the solar azimuth and the previously displayed menu will appear.

THE HUMIDITY SENSOR TEST

The Honeywell HIH-3605-A-CP sensor is a monolithic IC humidity sensor that provides a proportional voltage output to relative humidity. The sensor is buffered by an Op Amp and the output is connected to one of the analog input channels of the A/D converter. A temperature sensor is located near the humidity sensor to provide temperature compensation for the device. The two measured values, relative humidity and temperature allow the absolute humidity to be calculated.

The humidity sensor is supplied with a sensor specific data printout. The values of the data printout are entered into a formula, which calculates the moisture content inside the instrument.

The Calibration confirmation test consists of placing the sensor in a sealed container with a variety of water saturated salts that result in known, and accurate, RH values.

NaCl solution is 75.3%; the measured RH using the above formulas is 75.7%
$MgCl_2$ solution is 32.8%; the measured RH using the above formulas is 32.6%
LiCl solution is 11.3%; the measured RH using the above formulas is 12.3%
Dry N2 is 0%; the measured RH using the above formulas is 0.07%

These results show that the sensor is well within the range of its specifications

Method:
Attach the data printout from the humidity sensor container to this document.

Enter the values of origin and slope into the configuration file of the instrument.

Confirm normal operation of the instrument through the use of the routines TE and AP. Refer to the operators manual for specific use of these routines.

Model: IH-3605B Channel: 189 File 98080318
Wafer: thunder MRP: thunder

Pin 3: +5 VOLTS PRECISION SUPPLY
Pin 2: E+ SIGNAL OUTPUT
Pin 1: NEGATIVE or POWER COMMON

HYCAL Sensing Products
Honeywell Inc.
9C Founders Blvd
El Paso TX 79906
Calculated Values at 5V:
Vout @0%=0.868 @75.3%=3.050

Linear output for 2% RH accy @25C:
Zero offset = 0.868 V
Slope = 28.981 mV / %RH
RH = (Vout – 0.868) / 0.290
Radiometric response for 0 to 100%RH:
Vout = Vsupply * (0.1736 to 0.7533)

NaCl solution is 75.3%, the measured relative humidity is _____%
$MgCl_2$ solution is 32.8%, the measured relative humidity is _____%
LiCl solution is 11.3%, the measured relative humidity using is _____%
Dry nitrogen solution is 0%, the measured relative humidity is _____%

APPENDIX G PRELIMINARY DATA REDUCTION

This section describes how the Brewer software processes the raw photon-count data to determine ozone (O_3) and sulphur dioxide (SO_2) column amounts. Seven of the two-character menu commands (SL, SC, DS, ZB, ZC, ZP, M) access a common suite of data reduction algorithms, as shown in figure G.1.

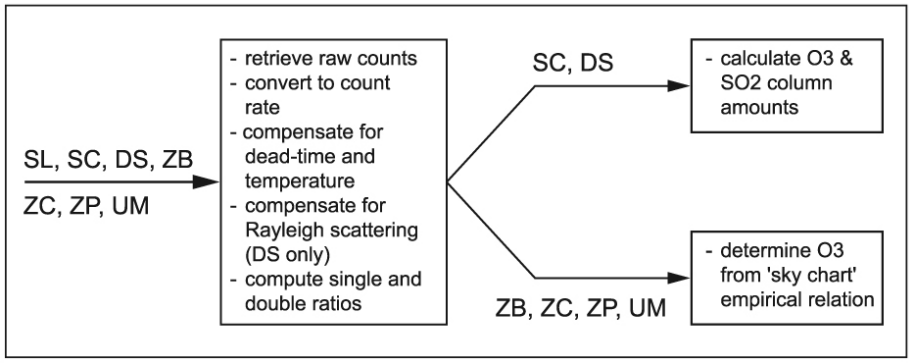

SL, SC, DS, ZB
ZC, ZP, UM
- retrieve raw counts
- convert to count rate
- compensate for dead-time and temperature
- compensate for Rayleigh scattering (DS only)
- compute single and double ratios
SC, DS
- calculate O3 & SO2 column amounts
ZB, ZC, ZP, UM
- determine O3 from 'sky chart' empirical relation

Figure G.1: Data Reduction Flowchart

CONVERTING RAW COUNTS TO LIGHT INTENSITY

Raw photon counts are automatically retrieved from six wavelength channels (one dark-count channel, five operational channels.
The computer requests raw photon-count data from the spectrophotometer by transmitting appropriate command strings, for example:

R, 1, 6, 20 (run the slitmask motor through positions 1 to 6, then back to position 1, accumulating the counts to six separate channels; repeat this sequence 20 times)

O (output to the computer the six photon counts measured in the previous R command)

The returned photon-count values are stored in the F() array. These raw values are written to the printer.

CONVERTING RAW DATA TO COUNT RATES

The core program subtracts the dark count (stored in F(1)) from the operational-wavelength counts, then scales the result to produce count rates, in counts per second:

$$F_i \leftarrow \frac{2 \times (F_i - F_1)}{CY \times IT}, \qquad i = 2..6$$

where

CY is the number of slitmask cycles (20 in the above example)

IT = 0.1147 is the interval-scaling factor which incorporates slit sampling time and duty cycle

COMPENSATING FOR DEADTIME

Poisson statistics are assumed so that for any observation at a true count rate F0 (counts/second) the observed rate F will be

$$F \leftarrow F_0 \cdot e^{-F_0 \cdot T_1}$$

where T1 is the deadtime of the photon-counting system (as determined by the deadtime test, DT, run as part of the Brewer setup procedures).
This equation is solved for F0 by iterating 9 times on the (rearranged) expression:

$$F_0 \leftarrow F \cdot e^{F_0 \cdot T_1}$$

This compensation is performed for each of the five operational wavelengths.
The deadtime-compensated count rates are normalized by computing the base-ten logarithm, then scaled by 104, thus allowing integer arithmetic.

COMPENSATING FOR TEMPERATURE

The count rates are corrected for the temperature-dependent bandpass characteristics of various filters inside the spectrometer assembly:

$$F_i \leftarrow F_i + (PC + TC_i) \cdot TE + AF_p, \quad i = 2..6$$

where

PC is the constant part of the temperature coefficient
TCi are the wavelength-dependent temperature coefficients read from the spectrophotometer's Constants File (stored on disk)
TE is the instrument temperature in degrees Celsius
AFp is the attenuation value of the neutral-density filters at position p (the array AF of attenuation values is also read from the instrument Constants File).

COMPENSATING FOR RAYLEIGH SCATTERING (DS ONLY)

If the reading is of the direct sun, the count rates are adjusted by compensating the effect of Rayleigh-scattering attenuation for the airmass calculated for the time of the observation:

$$F_i \leftarrow F_i + \frac{BE_i \times M3 \times PZ}{1013}, \qquad i = 2..6$$

where

BEI are the Rayleigh coefficients.
PZ is the atmospheric pressure at the site of the instrument (in millibars)
1013 is standard atmospheric pressure (millibars)
M3 is the airmass (also referred to as the path-lengthening factor) for a layer of height 5 km above the earth.
M3 is recalculated prior to each solar observation:

$$M3 \leftarrow \sec(\arcsin[k \cdot \sin(A)])$$

where

A is solar zenith angle
k = R / (R + Z)
R is radius of earth (6370 km)
Z is layer height (5 km)

These airmass calculations are imbedded within the "equation of time" computations.
A second path-lengthening factor, M2, is also calculated. This airmass corresponds to a layer height of 22 km.

COMPUTING SINGLE AND DOUBLE RATIOS

At this point the count rates Fi have been corrected and compensated for deadtime, temperature, and (if applicable) Rayleigh scattering. Four sets of single ratios are formed (recall that these count rates are in logarithm units, hence a "ratio" is formed by computing the difference):

$MS_4 \leftarrow F_5 - F_2$ (includes effects of O_3 and SO_2)

$MS_5 \leftarrow F_5 - F_3$

$MS_6 \leftarrow F_5 - F_4$ (affected predominantly by O_3)

$MS_7 \leftarrow F_6 - F_5$

Only the shortest of the five observation wavelengths (306.3 nm, count rate F(2)) is significantly affected by SO_2 column amounts, so ratios MS(5) , MS(6), MS(7) will be largely independent of SO_2 effects.
Two higher-order ratios are formed:

$$MS_8 \leftarrow MS_4 - 3.2 \cdot MS_7$$

$$MS_9 \leftarrow MS_5 - 0.5 \cdot MS_6 - 1.7 \cdot MS_7$$

Both of these functions have weightings which remove the effects of absorption which are linear with wavelength. In addition, they are stabilized with respect to small wavelength calibration errors. The second function is weighted to remove SO_2 absorption effects
These ratios are written to disk and printer.

DETERMINING O_3 AND SO_2 FROM DIRECT-SUN DATA

The O_3 amount, MS11, is determined from the logarithms of the count rates for the four longer wavelengths :

$$MS_{11} \leftarrow \frac{MS_9 - B1}{A1 \cdot M2}$$

where

MS9 is the double ratio described in the previous section
B1 is the extra-terrestrial coefficient for the O3 wavelength combination (instrument-dependent)
A1 is the differential O3 absorption coefficient for the O3 wavelength combination (instrument-dependent)
M2 is the path-lengthening factor for an ozone layer of height 22 km.

The SO2 determination is slightly more complicated because of the correction needed due to O3 :

$$MS_{11} \leftarrow \frac{MS_8 - B2}{A2 \cdot A3 \cdot M2} - \frac{MS_{11}}{A2}$$

where

A2 is the ratio of the SO_2 absorption coefficient to the O_3 absorption coefficient of the SO_2 wavelength combination; A2 is nominally set equal to 2.44

A3 is the differential O_3 absorption coefficient for the SO_2 wavelength combination (instrument-dependent)

B2 is the extra-terrestrial coefficient for the SO_2 wavelength combination (instrument-dependent).

DETERMINING O_3 AND SO_2 FROM ZENITH-SKY DATA

The determination of O_3 and SO_2 amounts from zenith-sky data is accomplished through the application of an empirical polynomial relation (a numerical "sky chart"). It is assumed that the O_3 function determined from zenith-sky observations can be analytically related to the value of the total ozone and the solar zenith angle. The relation assumed has the following form:

$$A \cdot X^2 + B \cdot X + C - F_{sky}$$

where

$$A \leftarrow a + b \cdot M2 + c \cdot M2^2$$
$$B \leftarrow d + e \cdot M2 + f \cdot M2^2$$
$$C \leftarrow g + h \cdot M2 + k \cdot M2^2$$

M2 is the path-lengthening factor for the O_3 layer
F_{sky} is the observed zenith-sky value
a, b, c, . . k are site- and instrument-dependent constants
X is the deduced direct-sun O_3 value.

It must be emphasized that the constants a . . k are NOT factory-set: they can only be determined after a large number (say 500 or more) of (Fsky, M2, XDS) data triples have been constructed from pairs of observations made on the direct sun (XDS, M2) and on the zenith sky (Fsky, M2). These data triples should span the full range of M2 and O_3 values.
The constants for instrument #15 are quoted here for reference:

a	+0.0164	d	+0.0396	g	-0.2778
b	-0.0836	e	+0.6326	h	-0.1262
c	+0.0185	f	-0.0705	k	-0.0122

Cloudy-sky (ZC) data are treated in the same way as the zenith blue-sky (ZB) observations: this is only a good approximation for thin cloud; satisfactory treatment of thick-cloud observations awaits development of an improved cloud-sky relation.

APPENDIX H COMPUTER / BREWER INTERFACE (TELETYPE)

The TT command gives an operator direct control of various Brewer functions by allowing low level commands to be sent directly from the Computer keyboard. With this feature, most useful as a troubleshooting tool, all motors can be moved, lamps turned on, and data sampled.
This command is useful only when the Brewer and Computer are communicating, and is sent from the Main Menu with the command, TT.
A copy of all transactions can be preserved if the print to disk has previously been turned on with the PD command, and a printout is requested after launching TelyType command.

Command Level
A command string consists of zero or more commands separated by semicolons, optionally followed by the A "command", and sent with 'Enter'.

Examples of TT commands:

B,2	- turn on the Quartz Halogen Lamp
M,1,0	- move the Zenith Prism to the 0 (Lamps) position
R,0,7,10;O;A	- run the shutter from position 0 to 7 a total of 10 times, - output the resulting counts, and - repeat until interrupted by "HOME"

When executing a command string, the Brewer executes each command set in turn. Commands within a command set are executed concurrently. The command set is assumed to have ended when the first command in the set has ended, even if other commands in the set are still executing. Any commands which generate output transmit that output in accordance to the rules of the low level protocol in effect.

Command strings terminating in the A "command" get repeated indefinitely. In the case of the computer interface low level protocol, an ESC command is required to terminate execution; in the case of the TTY low level protocol a break must be sent.

The following sections identify the various commands. Commands with single character opcodes constitute the commands supported by the COSMAC based Brewers. They are augmented by a number of commands supported only by later versions of the Brewer. These newer commands have multicharacter opcodes and provide functions specific to newer electronics or provide more natural commands for functions supported by the COSMAC based Brewers.

A number of the commands listed below are used only for diagnostics and are not nornally used in day to day operations, but are included for completeness. The commnds in more common use are marked by **.

Turn the the mercury lamp and/or the standard lamp on or off. This command requires configuration variables.

1. ** B

Syntax

B, <mask>

Parameters

The parameter <mask> takes one of four values or an error is logged:

<mask>	standard lamp	Mercury lamp state
0	off	Off
1	off	On
2	on	Off
3	on	On

*Note: if the configuration variable USE.B3.FOR.LAMPS is set to YES then the lamps are both turned on with B,3. If the configuration variable is set to NO then the state of the lamps are not altered and the command is essentially ignored.

Example

B,2

Turn the standard lamp on and the mercury lamp off, update lamp state variables in the background.

2. F

Define the fill characters to be used at the start of every transmission from the Brewer to the controller when using the TTY interface low level protocol.

Syntax

F,<count>,<ASCII code>

Parameters

parameter	range	Meaning
<ASCII code>	0 to 255	the character to be used as a fill character
<count>	0 to 255	the number of fill characters to use for each output message

Example

F, 1, 7

Transmit a single BEL character at start of each output message.

3. HVADJUST

Adjusts the High Voltage power supply. This command requires configuration variables.

Syntax

HVADJUST <delta>

Parameters

Parameter / response	Format	Meaning
<delta>	-128 to 127	steps to adjust the supply

Use of this command resets the NVRAM variable which keeps track of the latest measurement of the HV supply voltage. The watermarks are also centered around the new HV supply setting; note that this is different in operation from other watermarks.

4. ** I

Initializes the specified motor to its 'zero' position and set the corresponding step-count accumulator to 0; moves the motor to its default position. This command requires configuration variables. If the slow and maximum velocities specified for a motor are equal, then the motor reset routine is abbreviated, i.e., the movement does not include moving off the sensor and searching for it at a different speed than the maximum. I commands do not work concurrently (although on reset all motors initialize at once).

Syntax

I,<m>

Parameters

The following table gives the permissible values for <m>.

<m>	Motor	symbolic form of <m>
1	Zenith prism	ZENITH
2	Azimuth Tracker	AZIMUTH
3	Iris	IRIS
4	Filterwheel 1	FILTER.WHEEL.1
5	Filterwheel 2	FILTER.WHEEL.2
6	Filterwheel 3	FILTER.WHEEL 3
9	Micrometer 2	MICROMETER.2
10	Micrometer 1	MICROMETER.1
11	Slitmask 1	SLITMASK.1
12	Slitmask 2	SLITMASK.2
13	Zenith Tracker	TRACKER.ZENITH

Example

I,4

The motor used by Filterwheel 1 is initialized.

5. LOGENTRY

Report the next entry in the log

Syntax

LOGENTRY

Response

A character string identifying a problem. This string has the form

YYYY DDD HH:MM:SS <text>

where the text may be (for example)

1995 033 14:22:03 All log entries reported

Entry

LOGENTRY
1996 302 13:10:02 Warm reset requested. Tepid reset generated (RAM was corrupt).
Reading the oldest unreported log entry;
LOGSTART
LOGENTRY
1996 302 13:10:07 Motor #8: IIC communications error
LOGENTRY
1996 302 13:10:14 MUGWUMP: symbol not found
reading the oldest log entry;
LOGFINISH
LOGENTRY
1996 302 13:10:22 All log items reported
skipping past all the entries

6. LOGFINISH

Resets the log to act as though the newest entry in the log has already been reported.

Syntax

LOGFINISH

Example

see LOGENTRY

7. LOGSTART

Resets the log iterator to the oldest entry in the log.

Syntax

LOGSTART

Example

see LOGENTRY

8. ** M

Move the specified motor to the specified position. If the motor hits a limit sensor during its movement, then the motor is reset to its initial position and the requested motor position is again moved to. This command requires configuration variables. See the 10.31.7 for examples

Syntax

M,<m>,<s>

Parameters

The <m> identifies the motor to move. See the section on the I command for possible values.

The <s> defines the motion required. If <s> is positive the motor moves to the given position. If <s> is negative, the motor moves |<s>| steps backward and resets the 'zero' position of the motor to be this new position.

Example

M, 4, 256

Moves the translucent ground quartz diffuser on filterwheel 1 into the optical path.

9. ** O

Transmit to the controller all photon count data accumulated by the most recent R command, then zero the photon count accumulators. This command requires configuration variables.

Syntax

O

Response

<c0>,<c1>,<c2>,...,<cn>

Each count number returned is in the form of a decimal value using ASCII characters. Each number occupies exactly nine characters and the value is right-justified and padded with spaces. The last value in the list does not have a comma or space but a carriage return as expected.

Parameters

The <ci> are photon counts in the range 0 to 16777215, one for each slitmask position measured in the most recent R command.

Example

See section on the R command.

10. PMT

Reads a count using the PMT. This command requires configuration variables.

Syntax

PMT

Response

<count>

The count value (decimal number using ASCII characters) is right justified and padded with spaces in a nine-character string.

Parameters

Parameter /	format	meaning
<count>	0 to 2^{24}-1	the PMT count taken

11. ** R

Measure the light intensity. This command requires configuration variables. The configuration variable sets up the slit positions to correspond to a motor step position.

Syntax

R,<p1>,<p2>,<p3>

Parameters

<p1> may take values from 0 to 7, <p2> takes on values from <p1> to 7, and <p3> takes on values from 1 to 255. In response the Brewer measures the light intensity for each of the wavelength positions <p1> thru <p2> by running the slitmask from <p1> to <p2> and back accumulating the counts for each separate position. This counts are accumulated for <p3> repetitions of this back-and-forth scan. Every R command zeroes the count accumulators for all slitmask positions. See the notes on the configuration variable SLIT.PACE in section 5.19 Configuration Parameters.

If there are no parameters specified, the parameters from the previous R command are used. If no previous R command parameters had been specified (as would be the case after a warm start, for example) all of the parameters are assumed to be zero and no scan is performed. In essence, all that happens is the count accumulators are zeroed. The correspondence between <p1> or <p2> and slitmask position is given in the following table:

Slitmask position	meaning
0	Hg calibration: 302.1 nm
1	Dark Count
2	λ1 306.2 nm
3	λ2 310.0 nm
4	λ3 313.5 nm
5	λ4 316.8 nm
6	λ5 320.0 nm
7	λ2 & λ4 for Deadtime test

Example

R; O

0

If the above had been called before any other R command then a single zero is returned indicating that there were no scans taken.

R,2,4,4;O[sent to Brewer]

5638, 4996, 54886[returned by Brewer]

Sample and accumulate the light intensities for slitmask positions 2, 3,4,4,3 and 2. Repeat this sequence 4 times. In this example the O command is used to display example results. The returned counts correspond to slitmask positions 2, 3 and 4 respectively.

R; O[sent to Brewer]

5549, 4989, 54880[returned by Brewer]

In the above, the R parameters had already been specified as 2, 4, 4.

The new values returned correspond to a new run of the R command as specified.

12. S

Report the status of the most recent run command. This command requires configuration variables.

Syntax

S

Response

<p1>,<p2>,<count>,<p3>,0,<interrupted>,

Each number returned in the above string is in the form of a decimal value using ASCII characters. Each number occupies exactly four characters and the value is right-justified and padded with spaces. The last value in the list always has a comma. The number of parameters returned is limited only by the string length.

Parameters

The <pi> are the corresponding parameter from the most recent R command. The remaining parameters are given in the following table.

Response field	format	Meaning
<count>	0..<p3>	Number of cycles completed
<interrupted>	Boolean	on if the Run command was interrupted (by a break)

Example

S

2, 4, 2, 4, 0, 1,

Reports that the R command was R,2,4,4 and was interrupted during the third scan.

13. SAVE

Stores the current set of RAM configuration parameters in Flash memory.

Syntax

SAVE

Response

<retCode>

Parameters.

Response	format	Meaning
<retCode>	0 - 127	number of sets of configuration parameters for which there was room when the operation started. 0 means that no room was left and parameters are not stored

14. STEPS

Determines the number of steps in a complete revolution of the azimuth tracker. This command should always be immediately preceded by an I,2 command and followed by a ?STEPS query. This command requires configuration variables.

Syntax

STEPS

Example

I.2

Ensures that the motor or tracker position is accurately known.

STEPS

Moves the motor or tracker exactly one revolution and records the number of steps required.

?STEPS

17979

Reports that the most recent STEPS command discovered 17979 steps in a revolution.

15. T

Retransmit the output from the most recent non-null response.

Syntax

T

Response

Depends on which of the commands was most recent.

Parameters

The <pi> identify parameters being set, the <vi> give the values to which they are being set. The following table gives the permissible values for <pi> and the corresponding meaning for the <vi>.

Example

T[sent to Brewer]

1996 302 13:10:22 All log items reported[returned by Brewer]
The previous command string (which in this case was a call to determine the lamp state) was returned.

16. USECONFIG

Restarts software using the configuration in RAM.

Syntax

USECONFIG

17. V

Set the baud rate and the flag which controls echoing.

Syntax

V,<cps>[,<echo>]

Parameters

Parameter	format	Meaning
<cps>	byte	one of 30, 60, 120, 240, 480 or 960. The approximate number of characters per second. Baud rate set to 10*<cps>
<echo>	Boolean	on to suppress character echoing

Examples

V,120

The prompt ("->") after this command will be sent at 1200 baud

V,960,1

The prompt ("->") after this command will be sent at 9600 baud and character echoing will be suppressed.

18. CONFIGURATION PARAMETERS

A variety of configuration parameters define the operation of the Brewer. Commands exist to set and read each of these. They share a common syntax so the complete set are listed in the table below:

Syntax

?<name> or
?<name>[<index>]to read the configuration variable
!<name> <value> or
!<name>[<index>] <value>to write the configuration variable

Response

The <names>

Parameters

Parameter / response	Format	meaning
<name>	Identifier	starting address within the space
<index>	Identifier or number	which element of a vector of such values
<value>	Depends on <name>	depends on <name>

The <name>s

<name>	format of <value>	Effective	meaning of <value>
BREWER.ID	integer value (0-65536)	next warm start or USECONFIG	This is the Brewer ID used to manage multidrop protocol. Copied to NVRAM on initialization.
CLOSE.TIME	Float seconds	Immediate	number of seconds before the PMT window closes when we start to move the slitmask
IMMINENT	float seconds	Immediate	number of seconds before the PMT window closes that we should start to watch PMT window closely so we move the motor at the proper time
LAMP.RESET.TIME	float seconds	Next time lamp is turned on	The amount of time before the lamp will be automatically turned off.
LAMP.CONV.CURRENT [<lamp>]	float amps	Immediate	conversion constant for lamp current as measured at A/D
LAMP.CONV.VOLTAGE [<lamp>]	float volts	Immediate	conversion constant for lamp voltage as measured at A/D
MODEL	unsigned integer	immediate	the 'mark' number of the brewer
MOISTURE.LIMIT	float grams/cubic meter	on reset	Permitted maximum in watermark recording of moisture content inside the Brewer.
MOTOR.ADDRESS [<motorId>]	Unsigned integer (0-11)	Immediate	Identifies the 751 used to talk to this motor
MOTOR.CLASS [<motorId>]	one of: NOMOTOR MICROMOTOR TRACKERMOTOR STANDARDMOTOR SENSORLESSMOTOR	Immediate	The type of motor at this motorId and hence the algorithm used to initialize it.
MOTOR.INITIAL[<motorId>]	Signed integer steps	Immediate	position of motor from step 0 after initialization
MOTOR.MAX.ACC [<motorId>]	Unsigned integer paces/(256*tick)^2	on reset	maximum absolute value of motor acceleration to be permitted
MOTOR.MAX.JERK [<motorId>]	Unsigned integer paces/(256*tick)^3	on reset	maximum absolute value of rate of change of motor acceleration to be permitted inside a time slice
MOTOR.MAX.SEARCH [<motorId>]	Signed integer paces	on reset	max number of paces before search stopped
MOTOR.MAX.VEL[<motorId>]	Unsigned integer paces/(256*tick)	on reset	maximum absolute value of motor velocity to be permitted
MOTOR.MAX.POS [<motorId>]	Signed integer paces	on reset	maximum value of motor position to be permitted
MOTOR.MIN.POS [<motorId>]	Signed integer paces	on reset	minimum value of motor position to be permitted
MOTOR.ORIGIN [<motorId>]	Signed integer paces	on reset	position of step 0 after initialization
MOTOR.REF.PLAY [<motorId>]	signed integer paces	on reset	uncertainty of position of motor with respect to reference sensor when sensor is detected at high speed and arbitrary direction.
MOTOR.RESET.POS[<motorId>]	signed integer paces	during motor init	position of motor to be paced at before commencing motor init to ref sensor
MOTOR.SLOPE [<motorId>]	signed integer paces/step	Immediate	number of paces to a step (see M command)
MOTOR.SLOW.VEL [<motorId>]	unsigned integer paces/(256*tick)	during motor init	value of motor velocity to be permitted during final approach of search. If equal to max vel init routine is shortened.
MOTOR.STOP.METHOD [<motorId>]	int one of 1, 3 none 0 reduced 2 full	on reset	power applied for stopped motor
MOTOR.TIME.OUT [<motorId>]	float seconds	Immediate	amount of time that a motor is given to complete movement before timing out.
OPEN.TIME	float seconds	Immediate	number of seconds after PMT window closes before we open the PMT window
PMT.WINDOW.RESOLUTION	float seconds	Immediate	seconds in a window timing tick

PMT.WINDOW.TIME	float seconds	Immediate	seconds in a window. Should be an integral multiple of PMT resolution time.
RESET.TIME.OUT	unsigned integer seconds	on reset	the length of time allowed for initialization of all motors. This should be larger than the largest value of MOTOR.TIME.OUT.
RH.ORIGIN	float volt at 0 RH	immediate	Humidity sensor calibration provided by manufacturer
RH.SLOPE	Float volt/%	immediate	Humidity sensor calibration provided by manufacturer
SUPPLY.CONVERSION [<powerSupply>]	float	Immediate	Number of volts at the output of the supply to read one volt via the A/D
SUPPLY.DELTA[<powerSupply>]	float volts	on reset	Permitted (max-nominal and nominal-min) voltage in watermark recording
SUPPLY.NOMINAL [<powerSupply>]	float volts	on reset	Center voltage in watermark recording
TEMP.DELTA [<thermalPoint>]	float degrees	on reset	Permitted (max-nominal and nominal-min) temperature excursion in watermark recording
TEMP.NOMINAL [<thermalPoint>]	float degrees	on reset	Center temperature in watermark recording
TEMP.ORIGIN [<thermalPoint>]	float degrees	Immediate	number of degrees Celsius offset for 0 volts at the A/D
TEMP.SLOPE [<thermalPoint>]	Float degrees/volt	immediate	number of degrees Celsius per volt at the A/D (linear thermistors are used here)
TRACKER.DEBOUNCE.TIME	Float seconds	immediate	debounce time for the tracker control switches
USE.B3.FOR.LAMPS	Boolean	immediate	Sets response to command: B,3. If set to YES, lamps are turned on else the command is ignored.
VERSION.ELEC	unsigned byte	immediate	Records the electronics version
VOLTS.PER.BIT	Float volts	immediate	Resolution of A/D converter in volts per A/D unit (bit)

Possible <index>es

<index>	Meaning	possibilities/format
<address>	location within the space	ANSI C integer format[1]
<analogPt>	which A/D mux input	integer 0 to 23
<digitalPt>	which digital input	integer 0 to 15
<lamp>	which Brewer internal lamp	0 to 1 or identifier - One of: HG, STD
<motorId>	identifies a motor	see section on I command
<powerSupply>	identifies a power supply	0 to 6 or identifier One of: HV, +12V, +5V, -12V, +24V, +5VSEC (secondary supply), -5VSEC
<thermalPoint>	identifies a thermal sensor	0 to 5 or identifier One of: PMT (photomultiplier), FAN (internal temperature), BASE, BELOW.SPECTRO, WINDOW.AREA, EXTERNAL (external temperature)
<trackerSwitch>	identifies a tracker switch digital input	0 to 4 or identifier One of: CW, CCW, UP, DOWN, COARSE

Examples

?MOTOR.MAX.ACC[IRIS]
reports the current maximum acceleration for the iris motor.
!PMT.HV.TOLERANCE 50
sets the value of the high voltage tolerance to 50 millivolts.

[1] The first character must be a digit. The number interpreted as decimal unless the first digit is a 0 in which case the second character is tested. If it is 'x' or 'X' the remaining digits are interpreted as a hexadecimal number. If the second character is a digit the number is interpreted as octal.

19. OPERATIONAL INFORMATION

A variety of operational status values define the current state of the Brewer. Commands exist to set and read each of these. They share a common syntax so the complete set are listed in the table below:

Syntax

?<name>	or	
?<name>[<index>]		to read the status variable
!<name> <value>		or
!<name>[<index>] <value>		to write the status variable

Response

<value> ? form only

Parameters

parameter / response	format	Meaning
<name>	identifier	parameter in question
<index>	identifier or number	which of many
<value>	depends on <name>	depends on <name>

Possible Names

<name>	Format of <value>	writeable?	meaning of <value>
ANALOG.NOW [<analogPt>]	10-bit integer	no	A/D output value in A/D units
BREAK.ABORT.TIME	float seconds	Yes, reset to 0.25 on tepid resets	The elapsed time in seconds for a continuous TTY line-break to abort command processing.
BREAK.RESET.TIME	float seconds	Yes, reset to 5.0 on tepid resets	The elapsed time in seconds for a continuous TTY line-break to force a warm restart of the Brewer.
BYTE.X [<address>]	ANSI C integer format (Hex on output)	yes	value of the relevant byte in external RAM
BYTE.F [<address>]	ANSI C integer format (Hex on output)	no	reads value from Flash memory
BYTE.C [<address>]	ANSI C integer format (Hex on output)	no	value of the relevant byte in CODE space
BYTE.D [<address>]	ANSI C integer format (Hex on output)	yes	value of the relevant byte in DATA space
DIGITAL.INPUT [<digitalPt>]	OFF or ON	no	reads whether input is ON or OFF; logic levels are transparent to the user.
DIGITAL.OUTPUT [<digitalPt >]	OFF or ON	yes	digital output point ON or OFF with logic levels transparent to the user.
ECHO.SUPPRESSION	ON/OFF		Suppresses TTY mode echoing when ON, allows echoing when OFF.
HG.SWITCH	OFF or ON	yes	mercury lamp set OFF or ON
STD.SWITCH	OFF or ON	yes	standard lamp set OFF or ON
LAMP.POWER [<lamp>]	watts	no	lamp power consumption
LAMP.STATE [<lamp>]	lamp state type	yes	state of lamp (OFF or ON)
MOISTURE	Grams/cu. m	no	Moisture content of air inside the Brewer
MOISTURE.HIGH	Grams/cu m	yes	Moisture content high (watermark)
MOTOR.ALLSTILL	TRUE or FALSE	no	True only if all the motors have stopped moving

MOTOR.POS [<motorId>]	stepss	no	current motor position
MOTOR.LOST [<motorId>]	Boolean	no	current motor position unknown exactly
MOTOR.LIMIT.LOW [<motorId>]	Boolean	no	low travel limit sensor activated
MOTOR.LIMIT.HIGH [<motorId>]	Boolean	no	high travel limit sensor activated
MOTOR.REF.LOW [<motorId>]	Boolean	no	lower reference sensor (#1) activated
MOTOR.REF.HIGH [<motorId>]	Boolean	no	upper reference sensor (#2) activated
MOTOR.DISCREPANCY [<motorId>]	paces	no	position of the reference position on the most recent motor initialization. This is a measure of accumulated motor position error between the most recent and the immediately prior initialization.
MOTOR.ZERO.POS [<motorId>]	signed integer paces	no	the same as MOTOR.ORIGIN on a reset, but is updated by negative M commands.
PMT.SELECT	integer (1 to 3)	yes	selects the PMT in use; 3 means both
RH	%	no	Relative Humidity inside the Brewer
STEPS	integer steps	no	the number of steps in a complete revolution of the azimuth tracker
SUPPLY.VOLTAGE.HIGH [<powerSupply>]	volts	yes	supply voltage high (watermark)
SUPPLY.VOLTAGE.LOW [<powerSupply>]	volts	yes	supply voltage low (watermark)
SUPPLY.VALUE [<powerSupply>]	volts	no	supply voltage
SUPPLY.SETTING.HV	volts	no	HV supply setting recorded at last adjustment.
TEMP.HIGH [<thermalPoint>]	degrees	yes	lamp power consumption high (watermark)
TEMP.LOW [<thermalPoint>]	degrees	yes	lamp power consumption low (watermark)
TEMP [<thermalPoint>]	degrees	no	lamp power consumption
TIME	<year> <day> <hour> <min> <sec>	yes	-4 digits -3 digits -2 digits -2 digits -2 digits
TRACKER.SWITCH.SETTING [<trackerSwitch >]	ON/OFF	no	reports the debounced tracker switch status that is indexed
TRACKER.SWITCHES	integer bit map	no	bit is on if the switch (see <trackerSwitch) is currently pressed. These are debounced values.
TTY.FILL.CHARACTER	integer ASCII code (0-255)	yes	TTY mode echo character ASCII code
TTY.FILL.COUNT	integer count (0-255)	yes	TTY echo character padding count
VERSION.FW[<info>]	integer	no	Version information and design date for the firmware. <info> is one of: YEAR, MONTH, DAY, VERS, REL

Examples

?MOTOR.POS[IRIS]

reports the current position in half-step units of the iris motor.

!SUPPLY.VOLTAGE.HIGH[+5V] 5.00

resets the upper voltage watermark to the nominal value for the +5 volt supply.

Motor positions for instrument control

Motor # & Name	Step #	Position	Command String
1: Zenith Prism	0 1408 2112	pointing at standard lamp (internal) pointing at zenith sky (external) pointing at UVB port (external)	M,1,0 M,1,1408 M,1,2112
2: AzimuthTracker	0 14670	reference direction (North) reference direction, 1 full turn CW from step #0	M,2,0 M,2,14670
3: Iris	0 75 or 250	iris fully closed iris fully open	M,3,0 M,3,75 or M,3,250
4: Filterwheel #1	320 256 192 128 64 0	0: film polarizer (horizontal) 1: quartz diffuser (translucent) 2: blocked aperture (opaque) 3: clear aperture (transparent) 4: quartz diffuser; ND of f=2.0 (translucent) 5: clear aperture (transparent)	M,4,320 M,4,256 M,4,192 M,4,128 M,4,64 M,4,0
5: Filterwheel #2	0 64 128 192 256 320	0: f = 0 1: f = 0.5 2: f = 1.0 f = neutral density factor 3: f = 1.5[Attenuation = 10^f] 4: f = 2.0 5: f = 2.5	M,5,0 M,5,64 M,5,128 M,5,192 M,5,256 M,5,320
10: Micrometer #1	Approx 290	calibrated micrometer setting	M,10,xxxx
9: Micrometer #2		(nominal setting is 6±1.5mm; there are 576 steps/mm) (wavelength change of 0.006nm/step) (positive steps increase wavelength and decrease micrometer setting)	M,9,xxxx
11: Slit Mask	0 2 4 6 8 10 12 14	0: slit 0 (HG) 303.2 – 426.4 nm 1: dark count ---------- 2: slit 1 306.3 – 431.4 nm 3: slit 2 310.1 - 437.3 nm 4: slit 3 313.5 - 442.8 nm 5: slit 4 316.8 - 448.1 nm 6: slit 5 320.1 - 453.2 nm 7: dead time ----------	M,11,xxxx NOTE: R,0,6,2;O;A gives a real time listing of the registers from 0 to 6 press <<delete>> to stop.

APPENDIX I FIRMWARE LOG

Messages appearing in the Instrument Log (accessed using the RL command) have the following format:

yyyy ddd hh mm ss <message part 1>
yyyy ddd hh mm ss <message part 2>
...
yyyy ddd hh mm ss <message part n>

The 'yyyy ddd hh mm ss' identifies the time on the instrument clock at the time when the message was recorded. The possible values of <message part 1> are given below. Usually there is only the <message part 1>.

<name>: Bad arraySpacing, AddVectors().
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

<name>: Can't add preexisting symbol.
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

<name>: Enum type mismatch.
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

<name>: Hash table too full.
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

<name>: Symbol not found.
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

A command used only by one mode was entered in another mode.
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

Analog: initialization timed out.
During initialization the circuitry used to read analog input channels failed to initialize properly.

Attempt to exceed max boundary
An M command was issued to a position beyond the highest in the range of the motor. Instead it was moved to the highest legal position.

Attempt to exceed min boundary
An M command was issued to a position beyond the lowest in the range of the motor. Instead it was moved to the lowest legal position.

Bad command, no config variables:
A command was issued which required configuration when no configuration was loaded. The subsequent message indicates the command. If the instrument is in Cosmac mode at the time, it also responds immediately with "Sorry, need configuration variables."

Bad command string. Command string buffer cleared.
An illegal command was (not) processed. The subsequent message indicates the command.

Bad digital output setting. Only ON/OFF allowed.
(Self-explanitory)

Checksum bad in low level command.
During initialization, loadmode or opmode a message with a bad checksum was received. This is normal if an initialization starts while a packet is being sent and is of no consequence at that time. At other times it indicates a noisy communication line.

Command not accepted while another in progress.
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

Config signature did not write properly.
The configuration was not correctly written to Flash memory. Possibly the Flash memory chip has failed.

Flash config checksum error.
The data in the configuration is corrupted. Possibly the Flash memory chip has failed.

Flash config memory full.
Configuration can be saved to Flash memory(see SAVE command) only four times. Reload the firmware.

Lamp <number>: told neither ON, OFF.. what??
Only ON and OFF are valid settings for a lamp.

MAIN.C : motor initialization timed out.
Motor initialization failed to complete in the allotted time (RESET.TIME.OUT). Operation proceeds with the motors which did initialize.

Motor <number>: appears stuck with a reference sensor activated.
An attempt was made to initialize a motor but the motion which should have removed the blocker from a reference sensor did not do so.

Motor <number> became lost during M command.
Motor has been reset to its reference position.

Warning that a motor encountered an end of travel limit. This indicates that for some time prior to this message the motor was not in position.

Motor <number>: configured as nonexisting, cannot be moved/reset.
An attempt was made to move a motor which has been configured to a MOTOR.CLASS of NOMOTOR.

Motor <number>: IIC communications error
Error communicating with the controller for the given motor. If this error persists it indicates a failure in the instrument electronics.

Motor <number>: Motor busy.
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

Motor <number>: Motor lost.
The motor controller and the instrument controller are out of step. This error will be corrected next time the moter is moved. If this error persists for the given motor, please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

Motor <number>: Move attempted outside of logical bounds
An attempt was made to move the given motor out of bounds. If this error persists, please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

Motor <number>: Movement attempted with too large a jerk
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

Motor <number>: Movement attempted with too large an acceleration
Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

Motor <number>: Movement attempted with too large a velocity
If this error persists for the given motor, please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

Motor <number>: time allotted (<ss> seconds) for motor movement has expired. Motor stopped.
The value <ss> comes from the MOTOR.TIME.OUT configuration parameter.

New value set for watermark <nameOfWatermark>: <latestMark> <unitsOfWatermark>.
The indicated watermark value has been changed to <latestMark>. The possible watermarks are identified in Appendix H.

No Flash config segment in Flash to copy into RAM upon initialization
Attempt to initialize when no configuration information had been loaded yet. This message is normal as part of the process of loading new firmware.

Parallel command operation not supported:
A command was issued which requested that two operations run in parallel when that is not legal. The subsequent two messages indicate that the command is bad and present the command. The following commands cannot start while another command is still in operation: I, PMT, R, SAVE, STEPS, USECONFIG

PMT counter failure
The two independent counters on the PMT did not match count rates (differed by more than 2).Counter 2 has been disabled until explicitly re-enabled or until the instrument reinitializes.

Reset <requestedReset> -> <actualResetType> from <resetTime> until <restartTime>. Counts: <tepidResetCount>,<warmResetCount>

This is an information message. A message of this form is added each time the instrument initializes. The fields:

<requestedReset>

The type of initialization that was requested. Possibilities:

Warm	simply reset all the hardware to default settings
Tepid	rebuild the content of volatile RAM
Cold	rebuild the non-volatile RAM and volatile RAM, then reset all the hardware to default settings
No	not requested at all; either the power was cycled or the watchdog circuit restarted the firmware

<actualResetType>

The type of initialization that was actually performed. This can be

Warm, Tepid or Cold. The log is cleared unless this is Warm

<resetTime>

The last time read from the clock before the initialization started (e.g. just before power down). This is only guaranteed to be valid on Warm resets although it is normally valid for Tepid resets as well.

<restartTime>

The first time read from the clock after the initialization started (e.g. just after power up). This time may be incorrect on a cold start.

<tepidResetCount>

The number of tepid resets attempted since the last successful initialization

<warmResetCount>

Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances

The number of warm resets attempted since the last successful initialization

Resetting zero position illegal here:

When several motors are told to move simultaneously, none may move to a -ve step position, thereby resetting the actual position of 0. The subsequent message indicates the command which contains the error.

Second Flash operation attempted while one in progress in which this message was generated.

Unknown RCommand state called.

Please notify KIPP & ZONEN <info.holland@kippzonen.com> of the circumstances in which this message was generated.

APPENDIX J BREWCMD.EXE

The BrewCMD is a low level utility program to facilitate sending commands to and displaying responses from the Brewer. Hence it can be used for simple operation tasks. There are two versions of BrewCMD available:

1. BrewCMD.exe
   This version is a DOS based program and works fine with platforms such as W95 and W98, which are the most common platforms to operate the Brewer.bat software. This version of BrewCMD however does not work with WindowsXP.
2. BrewCMDW.exe
   The “W” extension indicates that this program is a Windows based program. This version works on XP systems. BrewCMDW does not work on MS-DOS, W95 or W89 systems.

To run the BrewCMD(W) utility the Brewer must be connected via the serial port of the PC. The BrewCMD utility is intended for the use of the scientist using the Brewer and the technicians installing the Brewer. The BrewCMD utility has three intended functions:

- To provide a tool for verifying the validity of connections to the Brewer and for verifying the low level message/response operation of the Brewer.
- Uploading firmware and configuration files.
- To facilitate sending commands to and displaying responses from the Brewer.

Note: The BrewCMD program is a low level utility. Using this utility can modify the calibration and equipment configuration information.

For information on how to upload firmware and configuration file please refer to the Service Manual.

KIPP & ZONEN
SINCE 1830

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